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The Resuscitation of the Comstock Mines.

IN all the world there is not to be found a parallel to the situation that existed along the Comstock lode twenty or thirty years ago. In mining and in engineering its products and its achievements stand out alone. As to the first, from a bit of sun-baked, barren, blasted rock and earth, three miles long and one-third of a mile wide, away up on the eastern side of Mt. Davidson, in Nevada, over $320,000,000 in gold and silver was taken by miners between 1860 and 1879 from a series of ledges of gold and silver sulphurets. From several of these ledges the four bonanza miners took out precious ore that in six years made them worth $137,000,000. In May, 1874, the Bonanza ledge—the richest body of ore ever known—was reached; in July, 1874, the mint began paying the bonanza firm $3,500,000 a month; in November, 1874, its net income was over $1,600,000 a week, and from May, 1874, to January, 1876, the California and Consolidated Virginia mine alone paid over $72,000,000. As to the second—its engineering achievements—Mr. Eckart's article, which follows, will speak.

Such Crœsan wealth warranted the exertion of herculean efforts in its getting, and the handiwork of the engineers of that day, now smitten with the blight of nearly twenty years of disuse and neglect, shows that, faithful to their trust, they erected marvelous mechanisms. But despite their strenuous exertions, despite everything that man or money could do, the water gained on their mastodonic pumps, and at last deep mining in the world-famed Comstock lode was abandoned.

It is particularly fitting that the engineering features of the principal ones of these now historic pumping plants should be reviewed at this time when modern machinery and modern engineering methods have begun to assault the fortress that was found to be impregnable some two decades ago. That eventual success will attend the present undertaking is unquestionable.

At present modern engineering has taken its initial step in the installation of an electric power transmission for furnishing cheap power to the mines in and about Virginia City, more commonly known as the Comstock mines. This transmission is now in operation; but before proceeding with a description of it, much knowledge concerning the difficulties to be overcome will be gained from Mr. Eckart's interesting article. For a number of years subsequent to 1878 Mr. Eckart was employed by the Government, as well as by different mining companies, in an engineering capacity to determine the working conditions, efficiency and cost of operating most of the largest surface and underground pumping, compressed air and mining appliances then in use, and his article is therefore authoritative.—THE EDITOR.

THE HISTORICAL PUMPS OF THE COMSTOCK.

BY W. R. ECKART, M. E.

NEARLY twenty years have now elapsed since most of the largest pumping plants for the Comstock were planned and installed. Criticism of the past from the standpoint of today, with the experience and advancement made in all pumping appliances before us, is liable to be harsh and unjust, for the defects are readily seen, while the causes that led to them are forgotten. Further, nearly every planned system in practice falls short of its calculated efficiencies, and is "handicapped and confused by the multiplicity of the commercial interests involved," and no mining district had greater difficulties to contend with in pumping than were met with by the engineers of the Comstock lode.

The completion of the Sutro tunnel and its employment for drainage purposes by the different companies changed nearly the whole system of pumps as originally designed. The costly and massive pump engines were left on the surface, while all intervening pumps were removed to below the tunnel level, where they were doubled up, two being placed at each tank station. This change left about 1700 feet of heavy pump rods between the surface engine and the first set of pumps. Double the work was being done on the lower end of the rods than was originally intended, and the fibers of the rods became "fatigued" and overstrained. Velocity diagrams taken from the pump rods underground showed that their motion was not regular or uniform with the surface engines. The effect of the elasticity and great length of the rods produced accelerations and their consequent strains, that many times exceeded the direct strain due to pumping alone. In the case of the Ophir rod at the 2400-foot level I found strains that exceeded the proper one by over nine times. The cause of the constant renewal of pump rods, broken balance bobs, pins and strapping plates that was almost a weekly occurrence at the mines was thus made apparent. As for the remedy, there was none with that class of pumps and machinery, located as it was at such a great distance from the water to be pumped.

For the benefit of persons not familiar with the magnitude and extent of the pumping plants erected and operated on the Comstock up to the years 1884 and 1886, a brief description is here given:

THE MEXICAN UNION.

The Mexican Union pumping engine was originally built in Europe as an overhead beam Cornish engine; was brought over, rebuilt, and changed to the compound condensing fly-wheel type. The cylinders are placed over the main beam and inclined to each other (Leavitt patent) with their connecting rods attached to the beam, one on each side of the beam center. The pump rod is connected at the pit end, and the connecting rod of the fly-wheel at the other. The fly-wheel is 36 feet in diameter and weighed with shaft 208,700 pounds. The wrought-iron beam under cylinders is 22 feet long between pump and fly-wheel pins, and weighed when completed with braces 238,610 pounds. The high-pressure cylinder has a diameter of 64 inches, 6 feet 9 inches stroke. Low-pressure cylinder is 100 inches in diameter and 8 feet 6 inches stroke. The air pump is single acting, 54 inches in diameter, 6 feet stroke. The nominal stroke of pump was 10 feet.

The engine was first started in April, 1880, with a double line of 14-inch plunger pumps discharging into Sutro tunnel. In January, 1883, the 14-inch pumps were replaced by ten 17-inch diameter plungers. In making this change a thousand feet of new 18-inch pump rods, with extra strapping plates, were put in. The pump rod, from the surface bob to the 2700-foot level, is 2618 feet long, and is counterbalanced by means of nine balance bobs, with from 18 to 20 tons in each bob. The total weight in motion while pumping was 1,620,500 pounds, or about 620 pounds for every foot of pump rod. The total lift from pump at the 2700-foot station to the lateral drift of Sutro tunnel is 1180 feet. On account of great length, elasticity and weight of the pump rod, the actual strokes of plungers averaged by measurements 9.7 feet, when the surface stroke was 10 feet. A similar loss of stroke is noticed on all the Cornish pumps used on the Comstock.

CHOLLAR, NORCROSS, SAVAGE.

The Cornish pump engine erected at the Chollar, Norcross and Savage shaft was similar in design to the Belcher and Overman. They are compound, vertical, condensing engines, controlled with Davey differential valve motion. The cylinders are placed vertically over one end of a truss beam, to the outer end of which is attached the main pump rod. The high-pressure cylinder is 32 inches diameter, with a stroke of 10 feet 9 inches. The low-pressure cylinder is 65 inches in diameter, 8 feet stroke. The walking-beam was 35 feet long and weighed 160,300 pounds. The strokes of the pumps and engines were variable, and were dependent upon the Davey valve motion, as no fly-wheels were used. The intended stroke was 8 feet; the actual stroke when measured was 7.6 feet. They used a double line of 15-inch diameter plungers, fourteen in all, when pumping from the 3180 level to the Sutro tunnel. (In 1886 water was raised 1570 feet.) The pump rod was 3155 feet long, had nine balance bobs, weighted with 19 to 21 tons each. Total weight in motion was 1,437,900 pounds.

The hydraulic system installed and started at this mine in May, 1881, consisted of a surface pump engine, compound condensing with horizontal cylinders, actuating direct from the cross-head, four pumps with plungers 8½ inches in diameter. The stroke, designed for 10 feet, was variable, under the control of the Davey valve motion. These pumps forced water into a large surface air chamber and from there down the shaft to the underground hydraulic pumps. The cylinders of this engine were 35 and 70 inches in diameter. An air pump and cooling pond were used for condensing purposes.

In each of the underground stations, cut at the 2400, 2600 and 3000 foot levels, as the shaft was sunk, there were placed two hydraulic engines. Each engine had four power plungers of proper size to operate two pump plungers that raised the water from the station to the Sutro discharge. The ratio of the power plungers to the pump plungers was properly proportioned, so that for a 10-foot stroke the pumps could make about six to seven strokes per minute. After a trial of a few months with numerous breaks and want of satisfactory results as to efficiency, the use of the surface power engine was abandoned. A 12-inch pipe was laid from the water company's tank near their flume, which gave a pressure head of 2016 feet to the Sutro level. With this steady power the pumps worked smoothly without a jar and gave very efficient results. Under this system of pumping all the water used for power was discharged with the mine water into the Sutro drain.

THE YELLOW JACKET.

The Yellow Jacket shaft had still another style of pumping engine, and at the date of construction, 1880, was considered as combining all the modern improvements that could be applied to a pump engine. It was so massive that a special car had to be constructed to transport some of the parts to the mine. The engine was of the horizontal compound type. The bed carrying the cylinders was a double box truss casting 64 feet long, to which the high and low pressure cylinders were bolted side by side, the piston rods being attached direct to one crosshead (weight 22,000 pounds). Between these rods in the center was the main journal of the crosshead, to which the pitman rod was attached, connecting direct to the surface balance bob that gave motion to the pump rods. There were two fly-wheels 30 feet in diameter weighing (new ones) 160,000 pounds, driven from connecting rods attached to the outer ends of the crosshead. The cranks of these wheels limited the stroke of the piston to 12 feet. The high-pressure cylinder was 31 inches in diameter, and the low-pressure 62 inches, both being steam-jacketed. The air pump was 36 inches in diameter, 6 feet stroke. The valve motion was of the Cornish double beat type, with adjustments so that steam could be cut off at any part of the stroke. The main surface or balance bob was proportioned to give the pump a ten-foot stroke. The boiler pressure to be carried was 130 pounds.

In July, 1880, the engine was started pumping water to the surface from the 3000-foot level with a single line of 14-inch diameter plungers. The total length of pump rod was 3055 feet, the weight in motion 1,510,400 pounds. The engine making 5.5 revolutions pumped 432 gallons per minute with 422 indicated horsepower. In November of the same year an accident to this engine closed down all pumping, until the Sutro tunnel having been completed to the shaft, the single line of 14-inch pumps was changed to a double line and was started up in April, 1881, pumping all water to the tunnel. The water was raised under these conditions 1516 feet, and the pump could be run at a speed to discharge about 700 gallons per minute. There were twelve balance bobs required, besides the surface bob, with their usual 18 to 20 tons of ballast for each bob.

In February, 1882, a heavy flow of water from the 2700 level of the Exchequer mine, estimated at 120 miners' inches, flooded the lower levels. The pump was run to its maximum capacity of 750 gallons per minute, the water still increasing, and not being able with pump and bailing tanks to control it, all pumping was stopped for good on March 28, 1882.

THE OPHIR MINE.

The pumping machinery of the Ophir mine was of the horizontal geared type. The diameter of steam cylinders was 24 inches, 5 feet stroke; the crank shaft carrying two fly-wheels of 14 feet diameter, and two sets of pinions with 21 teeth, 5-inch pitch, working with the main gears of 91 teeth. These wheels carried a crank pin between them, from which the pitman rod of 24 feet length was coupled to the surface bob. The stroke of the pump rod was eight feet at the surface and averaged 7.7 feet on the incline. There were five pumps 12 inches in diameter, single line. The vertical part of the pump rod extended to the 1465 level, where by means of an angle bob it went down an incline of 37 degrees to the 2500-foot level. The total length of rod was 3273 feet. There were six underground bobs with their usual balance weights. The inclined rod was carried on guide rollers 12 inches in diameter, weighing 180 pounds each. They were spaced about 25 feet apart. The weight in motion was approximately 1,067,500 pounds, and the water was pumped 960 feet to the Sutro drain, about 279 gallons per minute.

THE C. AND C. SHAFT.

At the C. and C. shaft works the pump engine was of the horizontal, tandem, Davey differential type. High-pressure cylinder was 24 inches diameter and low-pressure cylinder 40 inches diameter, 8 feet stroke. The pumps were intended for 7 feet stroke, but, as stated, with the Davey style of engines the strokes were variable, and they were never run to their maximum for fear of accident at striking points. At this shaft the engine averaged 7.6 feet stroke instead of 8 feet, which gave the pumps a stroke of 6.65 feet through the intervening bob. Water was elevated to the Sutro tunnel drains. The pumps could throw about 500 gallons per minute. The length of pump rods was 2150 feet, and the weight in motion when pumping was 860,000 pounds.

All of the above-mentioned pumping machinery cost, without foundations, installation or freight, about $1,300,000. Its maximum pumping capacity all told was less than 5400 gallons per minute, raised an average height of 1152 feet. The cost for six months, taken from the books of the different companies, for operating the same was $34.13 for one indicated horsepower per month. The average water pumped during that time was 5040 gallons per minute, raised an average distance of 1074 feet. The total indicated horsepower was 1703. The cost per month was $58,120, or $697,440 per year. This does not include the cost of new fly-wheels, broken bobs, strapping plates, pump rods or new plungers, but represents the daily operating expenses for pumping. The hydraulic pumps were handling 2128 gallons per minute at this time and the Cornish system was pumping 2912 gallons. To do this there were two and seven-tenths miles of pump rod, which, with its connected bobs, pumps and moving machinery, weighed 6,496,400 pounds, or 2230 pounds for every gallon of water pumped. This weight had to be started and brought to rest on an average of nine times per minute, and a train of cars over nine-tenths of a mile long would have been required to transport it. These great masses to which motion had to be communicated before water could be raised limited the work that could be accomplished. Any attempt to violate nature's laws resulted in an expensive and destructive break-down of the machinery, of which the log books of the different companies bear record. Increasing the size of pumps could not give a proportionate increase of pumping capacity, for any additional weight added meant a reduction of speed. As an example, for the year 1882 the Mexican-Union pump averaged 5.28 revolutions per minute with the 14-inch diameter pumps. In 1883, 17-inch diameter plungers were substituted and pump rods enlarged and strengthened. If the same number of revolutions could have been maintained the pumping capacity would have been increased 47 per cent., but the speed of the pumps was necessarily reduced for the first year after the change to 3.93, and the second year to 3.63 revolutions per minute as averages. A mean result was an increase of only 4 per cent. with more stoppages and repairs to the pump rods to contend with. The rods were already overstrained with the 14-inch pumps.

ENORMOUS OPERATING EXPENSES.

As for the enormous cost for operating expenses, it must be borne in mind that a great part was due to local conditions not to be found in any other mines the world over, hot water often reaching 160 degrees in temperature at an elevation of 6000 feet above the sea. (Weight of one gallon of water varied from 8.17 to 8.3 pounds.) Ice was one of the staples of supplies and lubricants for plungers and all underground bearings were rapidly consumed and otherwise wasted, and they required constant attention. Pump hoists costing from $20,000 to $40,000 were required and used to handle the massive rods and machinery in the pump compartments of the shafts. The wood burned cost $10 per cord, and in the previous years cost $12. One cord would evaporate 10,670 pounds of

water from and at 212 degrees, as an average of a large number of tests. This was the same as paying $22 per ton for coal. From January, 1882, up to January, 1884, the Chollar, Norcross and Savage Shaft Company paid $6000 per month for their power water to operate their hydraulic pumps, and $10,000 after that date. This water was furnished under a static head of 2016.5 feet to the Sutro tunnel level. As an average of six months' pumping in 1884, from the 2400 and 2600 levels with the hydraulic pump, the cost of water per one horsepower raised was $20 per month, a little more than the cost of wood used with the Cornish system. But in 1886, when the 3000-foot level pump was running, the price fell to $11.50 per pump horsepower, which was considerably less. For every gallon of water raised by the hydraulics on the 2400, 2600 and 3000 foot stations, there was 0.47, 0.543 and 1.04 gallons of power water required, respectively.

THE TRUCKEE-COMSTOCK POWER TRANSMISSION.

BY GEO. P. LOW.

THE electric power transmission of the Truckee River General Electric Company from Floriston, Cal., near the state line between California and Nevada and right on the line of the Central Pacific Railroad, to Virginia City, Nev., enjoys a dual distinction; first, in that it is the *open sesame* to every prospect of revivifying the old prosperity that at one time caused the Comstock lode to be regarded as Nature's treasure house, and, second, in that it is the only transmission in California which utilizes a water power from the eastern slope of the Sierras.

Stopping a moment for retrospection, it is surprising that the project of electrically transmitting power to the Comstock along lines in accordance with the plan of the Truckee River General Electric Company was not worked out and put into actual existence long ago. There were embodied in it all the elements for a successful outcome. There was the Truckee River, taking water from Lake Tahoe—that inter-state inland sea—which even with the unprecedented dryness of last season, gave over 2500 horsepower as a minimum without any effort whatever as to storage or other development; there were Independence and Donner Lakes and other sources, easily to be acquired, which could be developed into auxiliary water supplies that would give, if necessary, ten thousand horsepower; there was Tahoe itself, with all its tributary streams ever holding out the possibility of supplying yet larger powers. Then there was Truckee and Reno and Carson as small but desirable consumers, but above all were the mines of the Comstock, for years in a seemingly death struggle for their existence, burdened as they were with power bills of thirty dollars or so per horsepower per month, and with their scores of miles of drifts through ore bodies of inestimable value flooded under water hundreds of fathoms deep.

These were the conditions, in a general way, which existed when the Truckee River General Electric Company was incorporated by people who were largely interested in the Floriston Pulp and Paper Company, of Floriston, where are located the largest mills of the kind on the Pacific Coast. The question of providing cheap power to the Comstock had been under discussion among the mine owners of Virginia City for many months, but prior to taking active steps to obtain it, the mining interests had associated themselves into the Comstock Pumping Association in order that there might be a definite and responsible organization representing all the principal mines. This secured, the Association could act with authority. Its first efforts were exerted toward lowering the water in the submerged mines, and a hydraulic elevator was installed in the Consolidated California and Virginia shaft below the Sutro tunnel level (1650-foot level) which has now lowered the water by nearly 500 feet. This elevator is operated on the jet principle, using water under a head of 2400 feet and consuming 100 inches of water that costs $20 per inch per month. Nearly two years have been consumed in unwatering the mines to this extent—and in keeping the water down—and it has been very expensive. Moreover, the conditions are such that low efficiency prevails.

The unfortunate conditions existing were appreciated by the Pumping Association when it entered into a contract with the Truckee River General Electric Company on August 31, 1899, wherein it agreed to advance $100,000 to the Truckee River General Electric Company as an inducement to build an electric power transmission to Virginia City, said $100,000 to be rebated to the members of the Association in electric lighting and power service as stipulated in the contract.

This contract was drawn up after long and careful consideration between the "cheap power" committee of the Pumping Association, for which Dr. F. A. C. Perrine acted as consulting electrical engineer, and Mortimer Fleishhacker, president of the Truckee River General Electric Company, for whom the writer acted as electrical adviser. From an engineering standpoint it is a very interesting document* as it embodies features of value to managers who are confronted with stubborn load factor conditions. The contract is exclusive in that no other concern than the Truckee River General Electric Company can supply power to the mining companies during its life, and its initial period of existence is five years from the completion of the plant. It requires the electric company to maintain 2240-volt, three-phase service for 1500

*The Pumping Association consists of 27 mining companies which, together with the percentage of liability of each to the Truckee River General Electric Company under the contract, are named in the following list: Alpha Consolidated Mill and Mining Co, 1 per cent.; Alta Silver Mining Co., 1 per cent; Andes Silver Mining Co., 1 per cent.; Belcher Silver Mining Co, 7½ per cent.; Best & Belcher Mining Co., 7½ per cent.; Bullion Mining Co., 1 per cent.; Caledonia Silver Mining Co., 1½ per cent.; Challenge Consolidated Mining Co., 1 per cent.; Chollar Mining Co., 7½ per cent.; Confidence Silver Mining Co., 1½ per cent.; Consolidated California and Virginia Mining Co.. 15 per cent.; Consolidated Imperial Mining Co., 1 per cent.; Crown Point Gold and Silver Mining Co., 7½ per cent.; Gould & Curry Silver Mining Co., 7½ per cent.; Hale & Norcross Mining Co., 7½ per cent.; Justice Mining Co. 1 per cent.; Mexican Gold and Silver Mining Co., 7½ per cent.; Occidental Consolidated Mining Co., 1½ per cent.; Ophir Silver Mining Co., 7½ per cent.; Overman Mining Co., 1 per cent.; Potosi Mining Co., 7½ per cent.; Savage Mining Co., 7½ per cent.; Seg. Belcher & Mides Consol. Mining Co., 1 per cent; Sierra Nevada Silver Mining Co., 7½ per cent.; Union Consolidated Silver Mining Co., 7½ per cent.; Utah Consolidated Mining Co, 1 per cent.; Yellow Jacket Gold and Silver Mining Co., 7½ per cent. Although the foregoing aggregate 127 per cent., the liability of the mining companies to the electric company does not, by stipulation, exceed 100 per cent.

horsepower, which shall be measured in the sub-station at Virginia City. The contract then continues to state that

It is understood that in determining the amount of power to be furnished to and paid for by the mining companies, one mechanical horsepower shall be taken to be equal to 746 watts actual meter reading, and the number of horsepower to be furnished to and paid for by the mining companies shall be determined by the maximum demand reading of such recording instruments so furnished by the electric company, and, in determining what is the maximum demand or the maximum amount of power used by the mining companies during any month, the highest reading of the recording wattmeters for any period of time during such month exceeding five minutes, shall be taken, provided load equalizing devices be used by the mining companies for operating their hoists, but if any motor directly connected to a hoist be used, then the maximum demand shall be determined by the highest reading of said meters for any time exceeding two minutes.

The rates agreed upon by the contract insure to the mining companies the delivery of electric power at about 25 per cent. of the cost of steam power, these electric power rates being as follows:

For less than 2000 horsepower, $7.00 per mechanical horsepower per month.

Between 2000 and 3000 horsepower, $6.50 per mechanical horsepower per month.

Between 3000 and 4000 horsepower, $6.00 per mechanical horsepower per month.

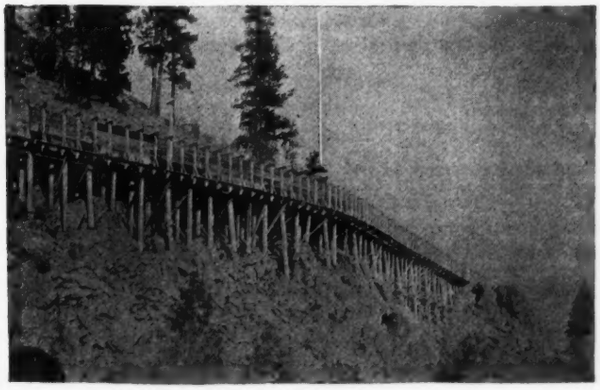
Between 4000 and 4500 horsepower, $5.50 per mechanical horsepower per month.

Between 4500 and 7000 horsepower, $5.00 per mechanical horsepower per month.

Over 7000 horsepower, $4.00 per mechanical horsepower per month.

THE WATER DEVELOPMENT.

The Electric Company's dam is situated close to the mills of the Floriston Pulp and Paper Company, at Floriston, Cal., on the main line of the Central Pacific Railway. It is of timber crib construction, rock filled and sheathed with double two-inch planking. The main structure is 142 feet in length and 7 feet in height, the cribs at each end being built up about 10 feet higher as a protection to the abutments in time of high water. The head gates, which are set into the head of a canal on the north bank of the river above the dam, consist of five openings separated by walls of 12 x 12 timbers built up into cribs above and at the sides. The gates proper are of wood, sliding in angle iron guides, and are operated by means of screw stems and hand wheels. Finally a zigzag fish ladder at one bank enables trout to pass above the dam.



A BIT OF SIDE-HILL FLUME CONSTRUCTION.

The canal is about 600 feet in length and 20 to 100 feet wide, forming a settling pond and providing a means of quiet entrance for the water into the flume. It was originally the old river bed, hence requiring but little excavation to make it fit for use as above described. At the lower end the water flows through a finger bar screen into the head of the flume, which is 28 feet wide at this point, converging in a length of 40 feet to its normal size. The finger bars, scour gate and spill-way are maintained in place by crib work similar in construction to that in the dam.

The flume is about 8600 feet long and is 6 feet 8 inches by 10 feet in the clear, of native pine, carrying 300 cubic feet of water per second, with a depth of 6 feet in the flume. The boxes are 12 feet in length, supported on bents spaced 16 feet centers, with two sets of four intermediate posts. At two points on the flume line are spill gates set in the sides of sand boxes below the bottom of the flume. In case of damage to any part of the structure, the water may be turned out at once through the nearest

DAM AND FLUME INTAKE NEAR FLORISTON, CAL.

set of spill gates without the delay necessary to operate the head gates at the dam. For two hundred feet back from the penstock a spill flume 5 feet 8 inches wide is built at the side of the main flume on a heavy grade to take the spill water when the penstock gates are closed. The penstock is of pine, 36 feet long by 21 feet wide, stayed with ¾-inch iron rods. Inside it is divided by a bulkhead into two compartments, from one of which two pipe lines lead. The flow of water to each pipe is controlled by three wooden gates in the bulkhead, operated by hand wheels from a platform above.

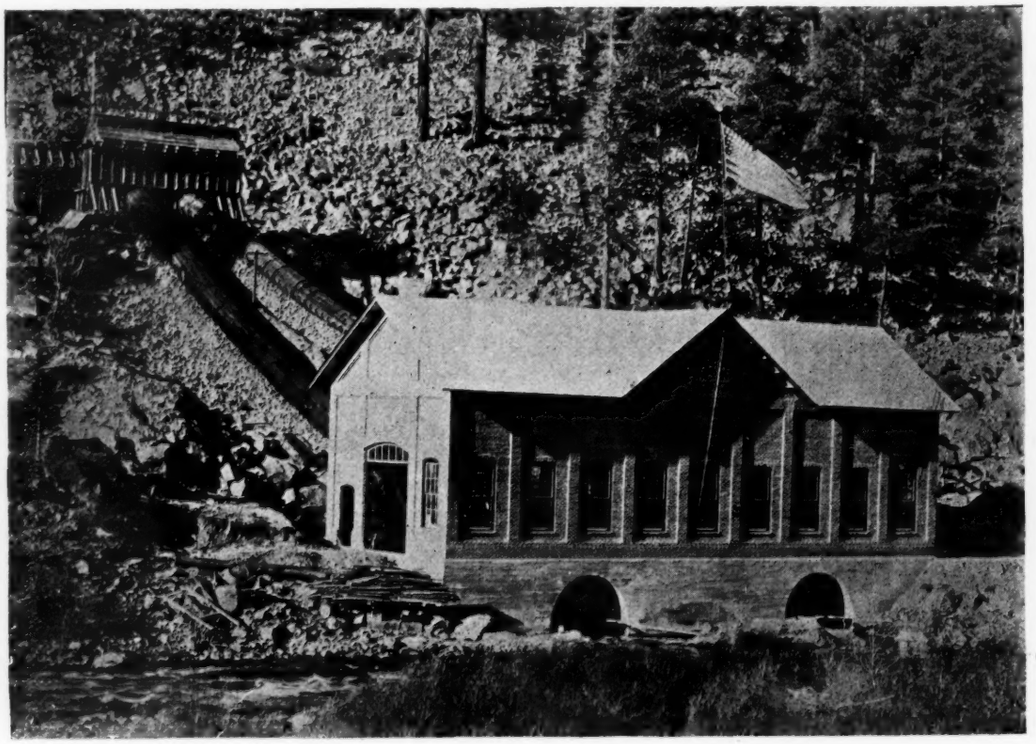
Water flows to the wheels through two lines of wooden stave pipe, 72 inches inside diameter and 160 feet long. The staves are of redwood, varying in length from 10 to 24 feet, and bound together with ⅝-inch round steel bands or bolts. Where joints come in abutting staves, a metallic tongue of ⅛-inch band iron is fitted into the ends of both. A few feet from the power house the wooden stave pipes are wedge jointed to steel pipes riveted on to the wheel cases.

Below the penstock, close to the river bank, stands the brick power house, the length of which inside is 88 feet and width 31 feet, the proportions, from an architectural

point of view, being relieved by a hip in the roof projecting toward the river. The foundations and tail races are of concrete and the roof of corrugated galvanized iron, supported on steel trusses and wooden purlins. The interior is well lighted by windows of ample size. All low-potential cables are carried in six-inch ducts of glazed sewer tile imbedded in the concrete floor, and the station is served by a twelve-ton hand crane supported on heavy I beams running the length of the building on brick pilasters projecting from the walls and spaced 10 feet centers. The tail races are 18 feet in depth, with roofs formed by springing concrete arches between steel I beams, and concrete floors protected by heavy planking six feet below the level of minimum water in the river.

THE POWER HOUSE.

ated by a wire rope passing over the sheaves, one mounted on the shaft of one of the gates, the other on a short countershaft. The lever operating the valve is placed between the sheaves and the wire rope fastened to it in such a manner that the revolution of the gate shaft in opening or closing the gate closes or opens the valve in the opposite direction, thus maintaining an approximately constant velocity of flow in the pipe lines whatever variation of load may be taking place. The valves discharge into the tail races of the wheels and are connected to the wheel casing by a short length of steel pipe. At first sight this arrangement may appear wasteful, but in reality, since no storage of water is necessary, were the water not wasted through the valves at time of light load, it would merely spill over the flume or dam. The great



PENSTOCK, PIPE LINE AND POWER HOUSE OF THE TRUCKEE-COMSTOCK TRANSMISSION.

The main water wheel equipment consists of two pairs of 27-inch horizontal turbines, each pair capable of developing 1400 horsepower at 400 revolutions per minute, under a working head of 84½ feet. The main body of the wheel casing is of heavy plate steel, and the buckets of the runners are of cast steel with heavy bands around them. To each wheel case are riveted heavy cast-iron brackets, the bases of which are planed to fit similar brackets on the supporting I beams. Each pair of turbines discharge into a cast-iron draught box in the center of the casing, to which is riveted a single draught tube. The tubes taper in about 20 feet of length from 54 inches to 72 inches at the lower ends and reach tail water at an angle of 45 degrees.

Each set of turbines is provided with a turbine governor operating the gates, and also a balanced valve oper-

gain in regulation due to constant velocity can only be appreciated upon considering the time consumed in overcoming the inertia of the large mass of water in the pipes.

To each set of wheels is coupled one 750-kilowatt Westinghouse three-phase, 500-volt generator, the generators themselves being so arranged that they can readily be direct connected by a rigid coupling; thus both may be driven by one wheel set. The flexible couplings between generator and water wheel are of the leather link type designed some years ago by the electric company's engineers, and are now largely in use in effecting direct connection between water wheels and dynamo shafts. They consist of disks keyed on the shafts of the generator and wheel, each disk having four steel pins. The pins on the two flanges are connected through leather links,

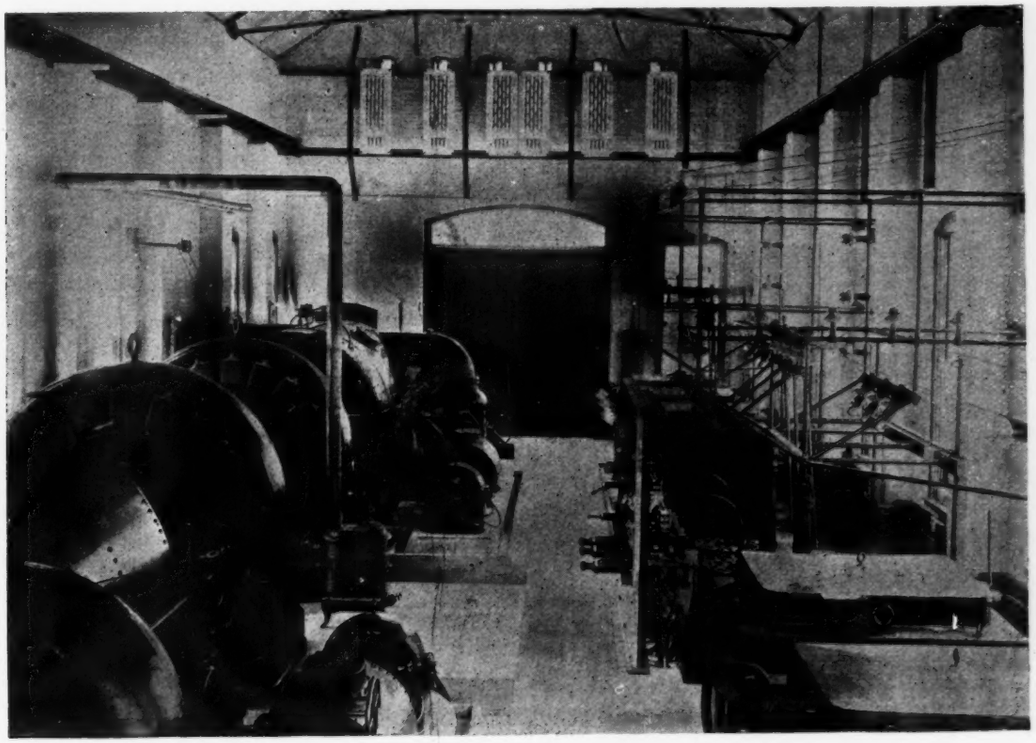
the coupling, as a whole, forming a most satisfactory means of flexible connection.

The exciters—two 22½-kilowatt machines of the multipolar type—are driven by separate turbines at at 975 revolutions per minute. Either one has sufficient capacity to excite the fields of both generators. The exciter turbines are connected by a short length of pipe to the casings of the large wheels and discharge into their respective tail races.

The low-potential switchboard is of the usual type, consisting of one exciter panel and two generator panels, with the necessary instruments and switches to permit the single or multiple operation of both exciters and generator fields and the operation of each generator with either or both sets of three oil-insulated, 500 to 22,000 volt transformers, or of the two machines in multiple on either or both sets. The leads from the high-tension side of the transformers run directly up overhead to the high-potential switches, which were made by the Electrical Engineering Company of San Francisco, and consist of a frame work of gas pipe to which pins and glass insulators are secured. The handles of the switches are of wood, enclosing a fuse which connects the copper terminal at the extreme upper end of the handle to the contact jaw secured to the wood near the lower end. The opposite contact clip is secured to the bottom of a pin screwed into a glass insulator fastened to the iron frame work. Thus all the high-potential wires are run on glass insulators only, the jaws on insulator and handle serving to make and break the circuit. The switches are so arranged that either or both sets of transformers may be connected to either side of the double three-phase transmission line, or both sets may be operated in multiple on either or both circuits.

From the high-tension switches and lightning arresters, the two circuits are run through openings high up in the power house wall, under the gable, directly to the first pole of the transmission line. The poles are of redwood 11 x 11 inches at the butt, 7 x 7 inches at the top and 30 feet long, carrying two crossarms and two brackets for telephone wires. The lower crossarm carries four No. 4 B & S gage copper wire on oil-treated eucalyptus pins and 7-inch Locke annealed glass triple-petticoat insulators, while the upper arm carries the third wires of each circuit. Transpositions occur at intervals of 144 poles. The line from the power house to the sub-station traverses rather a rough country, and for the greater part of the 33 miles the poles are placed 130 feet. The full-load line loss at 22,000 volts with the two circuits in parallel is slightly in excess of ten per cent.

THE LINE AND DISTRIBUTION.



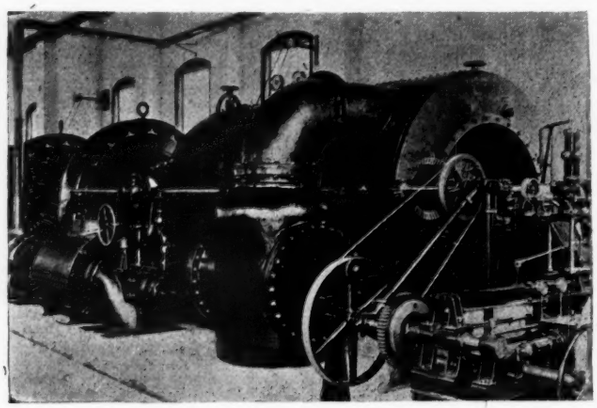
GENERAL VIEW OF THE INTERIOR OF THE POWER HOUSE.

In view of the fact that the Consolidated California and Virginia shaft demands the maximum amount of delivered power, the sub-station at Virginia City is situated close to its works. Here current is delivered to two sets of three transformers and distributed to the switchboards at the various mines at 2250 volts, three-phase. The building is 50 feet by 24 feet, of corrugated, galvanized iron, containing a bedroom, storeroom and office, beside the room necessary for operating the station. The high-tension switches are of the same type and arranged in the same way as those at the power station. The low poten-

tial, or distributing switchboard, is of white marble in six panels, two of which are receiving, and four feeder panels. Instruments and switches are arranged in such a manner as to maintain the maximum flexibility of operation, which is a feature at the power station.

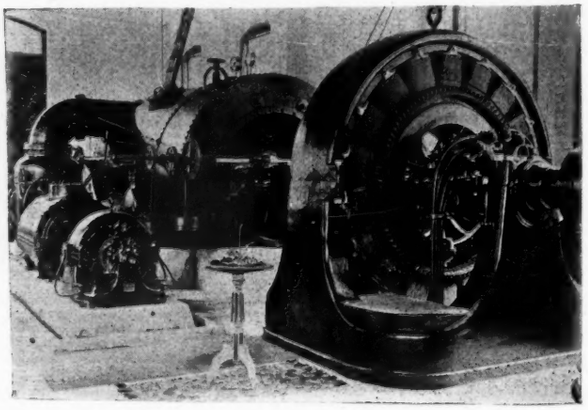
To meet the conditions of measurement of power delivered as imposed by the clause of the contract above quoted, a special form of indicating and recording wattmeter having a capacity of 1500 kilowatts was designed, and the accompanying engraving illustrates the instrument as manufactured by the Wagner Electric Manufacturing Company of St. Louis.

The meter is constructed upon the two-wattmeter method of measuring the power in a three-phase system of distribution. One meter is placed above the other and

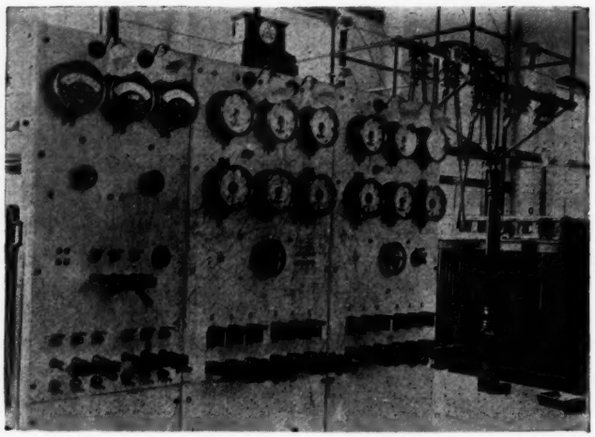


A TURBINE SET, SHOWING GOVERNOR AND BY-PASS ARRANGEMENT.

the movable coils are connected rigidly to a commo shaft which rests in jewel bearings at either end. These coils are arranged so that the field of one meter does not affect the other. Series transformers furnish the current coils of the meter with a small portion of the total current in the line. The pressure of 2300 volts is reduced to 115 volts through a pressure transformer for the pressure circuit. The meter is designed to take care of inductive loads, and has a central zero. No constant is necessary, as the scale is direct reading. The recording attachment consists of an aluminum disk rotated by clock work, and located beneath the pointer. The disk carries a paper disk with duplicate calibration of the indicating

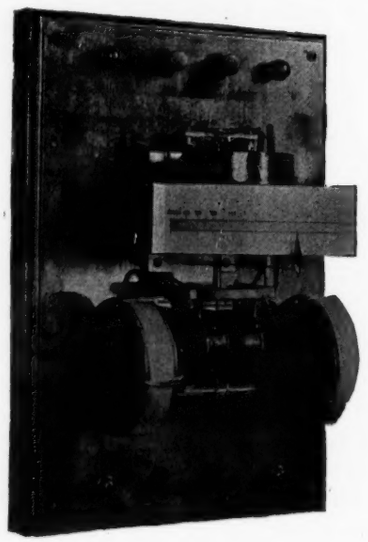


A COMPLETE UNIT, WITH EXCITERS AND TURBINES.



SWITCHBOARD AND HIGH-TENSION SWITCHES AT THE POWER HOUSE.

scale. The disk rotates every 12 hours, and one paper disk will serve for 24 hours' record. The load curve is traced on the disk by means of a static discharge from the pointer which perforates the paper disk. This curve may be intensified by placing the sheet on a colored ink pad. With this arrangement it is possible to have a permanent record of the power used at the mine, which information is valuable where the cost of power has a peak-load time limit, and especially so in the present instance, where, in order to produce a record that will show definitely the highest two-minute load reading, which is the only part of the record required in determining the power to be paid for, the paper disk is made 14 inches in diameter and rotates once an hour for twelve hours, the highest peak for a period of two minutes being readily determined. The 2250-volt distribution system from the sub-station at Virginia City is similar in construction to the transmission line. It consists of four circuits of insulated copper wire, the longest of which is two miles. The loss between any of the mines and the sub-station in no case exceeds four per cent.

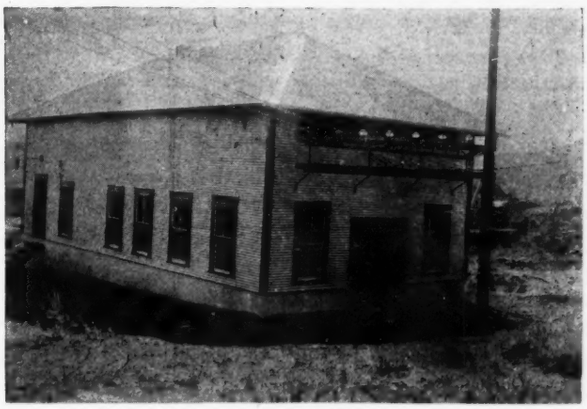


THE 1500-KILOWATT INDICATING AND RECORDING WATTMETER.

The application of electric power at the mines is being made as rapidly as the necessary apparatus can be obtained. Electric hoists will be installed, using the balanced tail-rope system driven by direct-geared 200-horsepower induction motors. The air compressors are to be belt-driven and provided with automatic by-pass valves on the cylinders, controlled by the air pressure of the receivers, and so arranged that the by-pass valves are either full open or closed, the speed of opening or closing

being adjustable. Current for the underground stations is carried down the vertical shaft of the Consolidated California and Virginia to the 1750-foot level by means of a three-conductor, lead-encased cable protected by a steel-wire armor. A 100-ton mill with two sets of grinders and three sets of concentrators is equipped with six induction motors, one for each set of grinders, concentrators and the rock-breaker. Ore from the Gould and Curry mine is brought to the mill by a small direct-current haulage equipment, to which current is furnished by a 220-volt direct-current generator belt driven from an induction motor.

Plans are being prepared by Leon M. Hall, engineer for the Comstock Pumping Association, for an extensive electric pumping equipment to take the place of the jet



SUB-STATION AT VIRGINIA CITY, NEV.

pumps now in use, engineering descriptions of all of which will be given in the columns of THE JOURNAL in due season.

Construction work on the Truckee River General Electric Company's plant was commenced on the second day of January, 1900, and current delivered in Virginia City for the first time on September 29th, regular service being started on October 20th. The Engineering Offices, of San Francisco, had in charge the entire engineering work connected with the design and installation of the plant, and the Pacific Construction Company were contractors for the erection of dam, flume, pipe lines and building.

* * *

ENGINEERING DATA OF THE TRUCKEE-COMSTOCK TRANSMISSION.

Hydraulic:

Dam—Crib rock-filled; 142 feet long, 7 feet high.
Canal—600 feet long, from 20 feet to 100 feet wide.
Flume—8600 feet long and 6 feet 8 inches x 10 feet in the clear; capacity, 300 cubic feet per second, with 6 feet of water.
Pipe line—Wood stave, 160 feet long, 72 inches inside diameter.
Turbines—Two pairs 27-inch horizontal McCormick, each developing 1400 horsepower at 400 revolutions per minute; installed through Pelton Water Wheel Co., sole Pacific Coast agents for S. Morgan Smith.
Head—84½ feet.
Governor—Type "B" Lombard.

Power House:

Building—88 feet x 31 feet inside, concrete foundations, brick sides, corrugated iron roof.
Generators—Two 750-kilowatt, 500-volt, three-phase Westinghouse, direct connected to turbines; speed, 400 revolutions per minute.
Exciters—Two 22½-kilowatt multipolar Westinghouse, 125 volts, at 975 revolutions per minute.
Transformers—Six 250-kilowatt, 500 to 22,000-volt, oil insulated, air cooled.

Pole Line:

Poles—Redwood—11 x 11 inches by 7 x 7 inches by 30 feet, with two crossarms and two brackets for telephone wires; spaced 130 feet apart.
Line—Power circuits, six No. 4 B & S gage copper; telephone No. 14 Birmingham wire gage, galvanized iron.
Length—33 miles.
Pins—Oil-treated Gillespie eucalyptus.
Insulators—Locke 7-inch triple-petticoat annealed glass.
Transpositions—Every 144th pole.
Loss—Ten per cent. under full load at 22,000 volts, both circuits in parallel.

Distribution:

Sub-station—Corrugated iron, 50 feet x 24 feet.
Transformers—Six 250-kilowatt, 20,000 to 2250-volt, oil insulated, air cooled, Westinghouse, delivering three-phase current.

Miscellany

CHARACTERISTICS OF ELECTRICAL INSTRUMENTS.

VARIOUS forms of commercial electrical measuring instruments that are in commercial use, especially in Great Britain, were recently discussed in a paper read by E. S. Shoults before the Northern Society of Electrical Engineers,* wherein the author depreciates the use of dials of a larger size than nine inches, on the ground that excessive weight, inertia and friction accompany their use. He finds that instruments of the D'Arsonval type are not affected under ordinary conditions by stray magnetic fields, and also that very satisfactory results may be obtained from instruments fitted with the McWhirter shielding device† which consists in replacing the brass cheeks or heads of the main coil of any ordinary electromagnetic instrument by cheeks of iron about one-quarter of an inch thick, and then slipping over the whole bobbin a tube of iron of like thickness. In one instrument the disturbing effect was reduced from 16 per cent. to 5.9 per cent., and in another from 30 per cent. to 0.75 per cent. The errors introduced by residual magnetism are very small and may be neglected in practice. As to alternating-current instruments, the author believes that a shielded bobbin is quite as good as a plain one, provided that the iron is worked at a low induction density and is laminated.

Finally, some experiments made to determine the forces dealt with in certain well known types of instruments as found on the English market, gave the following results:

Type of Instrument.	Watts used in Active Part.	Torque per Watt in Grammes at 1 cm. radius.	Deflection in Degrees.
Kelvin Balance	70 9	25.19	..
Kelvin Gage	6.4	0.295	45
Dolivo Voltmeter	0.8	0.187	75
Stanley Vo'tmeter	1.4	0.139	72
Stanley-McWhirter	1.4	0.195	72
Nalder Voltmeter	0.6	0.415	70
Evershed Voltmeter	1.17	40.184	78
Weston Pattern	0.0012	472.00	84

Let me congratulate the JOURNAL—or rather the electrical interests—on its appearance.—*F. B. Herzog, Ph. D., New York.*

*See *Science Abstracts* No. 2046, (1900.)

†*Ib.* No. 521 (1898.)

THE JOURNAL OF
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EDITORIAL.

THE MARKET FOR POWER.

Never a day passes that does not bring up an inquiry implying doubt on the part of some worthy, astute layman concerning the possibility of finding utilization for the vast amount of mechanical energy that is being developed by steam and gas engines and distant waterfalls, for consumption in industrial centers. In general, the amount of power development in specified rural localities is only sufficient to fulfill the immediate localized demands, such as the operation of a given number of mines or the pumping of water for the irrigation of certain horticultural areas, or the performance of general power duty, but in metropolitan or other districts specially favored for manufacture and commerce, where the proposed supply exceeds the present consumption, it certainly appears to the aforesaid layman —who at best is superlatively superficial—as though the business of supplying power is very liable to be overdone, and especially as through the development of water powers for transmission purposes, for instance, was being seized upon by capitalists as an acute fad—indeed with Belgian-hare-raising idiocy.

To take a specific instance: The chief cities around the Bay of San Francisco are at present consuming, let us say, on a conservative estimate, approximately 125,000 horsepower, all of which is at present developed by the steam engine. Within three months there will come the Standard Electric Company's transmission, with its present 10,000 horsepower and its prospective 20,000 horsepower additional and closely following will come the Bay Counties Power Company's transmission with a capacity of another 20,000 horsepower. Still further, the Mammoth Power Company will, in all probability, be delivering 25,000 horsepower in San Francisco within the next five years from the San Joaquin River. The first of these three projects will be operating in Stockton, Oakland, San Jose and through at least to Redwood City during January next over the most remarkable transmission line in the world. The second will in all probability reach Oakland within a month or six weeks after the advent of the Standard power into that city; and the Bay Counties line, coming as it does for 138 miles at at least 40,000 volts, is also a very extraordinary engineering enterprise. But capping all will be the Mammoth transmission. It proposes to develop power from the main San Joaquin river, high in the Sierras, whence the water will be taken through some fourteen miles of tunneling to a point in the canyon where a 2000-foot head will be available. Here 30,000 horsepower will be developed for transmission to San Francisco at 70,000 volts over a double pole line about 180 miles in length. Messrs. Balfour, Guthrie & Company are reputed to be the agency through which the financial sinews of the Mammoth project are being furnished—indeed Mr. Guthrie is president of the Mammoth company. There is every reason to believe that the project is a *bona fide* one and that it will be carried through to completion in the earliest possible time.

In the meantime herculean efforts are being put forth by the Standard and Bay Counties companies to complete their projects without delay. For two years past an army of men have been perfecting storage facilities in the Blue Lakes water shed so that henceforth the repitition of any known drouth in California will not be able to affect the continuity of the water supply of the Standard Electric Company. Of the two enterprises, that of the Standard company is at present the more ambitious, in that its electric service is being carried on to San Francisco at once, while that of the Bay Counties company proposes to end at present at Oakland, after having passed through the cities of Marysville, Sacramento, Benicia, Vallejo, Mare Island, Port Costa and the smaller, but by no means inconsequential localities en route. It is the policy of THE JOURNAL to decribe in detail that which *is*, rather than that which *is to be*, in accordance with which these columns will, in due season, relate all that is to be said concerning these new transmission enterprises; but in the meantime, in order that a slight conception may be had of the novelties and innovations that are being worked out in this line, reference will now be made to but a single feature—that of the great span in the transmission line of the Bay Counties company, across the Strait of Carquinez.

Passengers on Southern Pacific trains en route from Port Costa to Oakland, Cal., can hardly fail to notice the great steel tower that is being erected on a high bluff across the Strait of Carquinez shortly after the train leaves Vallejo Junction on its journey to Oakland. This structure is one of the two towers that is to support the cables forming a link in the transmission line of the Bay Counties Electric Power Company between its power house at Colgate, on the Yuba River, and Oakland, Cal., a distance of 138 miles. The other tower is on the bluff in Contra Costa county just above the railroad track, and the great span, which will have a length of approximately 4700 feet, will pass across the strait and over the town of Crockett, where a beet sugar refinery is located.

This span is indeed a very remarkable piece of engineering and its great length alone marks it as a characteristic of the incomparable energy of engineering in the far West. The towers, which are of structural steel, are 86 feet square at the base and will be carried to a height of 240 feet, which, taking into consideration their position on bluffs, will give the span a clearance of 200 feet above the level of the water, with a sag of 135 feet. The cables to be used are now on the ground and they will be four in number, each being of plow steel in 19-wire strands and having a diameter of seven-eighths of an inch. Each cable will exert a pull of twelve tons on each anchor, in view of which, taken in consideration with the fact that the cables are to carry the transmission current at 40,000 volts and eventually at 60,000 volts, a nice problem is presented in giving the cables adequate insulation with the requisite mechanical strength. Combination porcelain and glass strain insulation weighing approximately fifty pounds each and of heroic size are to be used, two in series, on each end of each cable, and the four cables will be swung, two on each side of the towers, and "staggered" so that they cannot approach one another within twenty-five feet. As the line is a three-phase, three-wire transmission, the fourth cable is in reserve.

This span, which will be completed during December of the present year, will be the longest in any power transmission line in the world, the next in length in the West being that of the Bonnington-Rossland (Kootenay, B. C.) transmission, which stretches across the Columbia River, a distance of 1500 feet.

These facts have been related that the reader may become aware of the magnitude of the electric power transmission enterprises in that portion of California which is contiguous to the Bay of San Francisco, and also that he—if perchance he be in that unfortunate state of intellectual sophistication which leads to the conviction that he knows, by virtue of his keenness of observation, all there is of science and commerce and industry and engineering (there are such people, you know)—may fully realize that men of hard dollars and harder sense have taken the advice of their engineers and have invested fortunes in enterprises for the delivery of the commodity of power in material quantities in excess of immediate demands. It is not rational to assume that the advent of electrically transmitted power means the displacement of an equivalent amount of, say, steam power. Many power users are wedded to the steam engine, or at least they think that investment in steam plant, or the costs of changing to electric power, or perhaps the magnified value they hold of the efficiency of their engines and boilers, constitutes holy bonds of wedlock that cannot be severed.

And apropos of magnified values, is it not sometimes a strange thing, this mind of man's? Verily it is, and here is a case in point: A certain well-known manufacturing plant carries a steam pressure of 125 pounds per square inch in its boilers. Most of the steam is used for power purposes, but considerable of it is used for steam heating in manufacturing processes. The engineer believed it to be unnecessary to supply steam at 125 pounds for the heating process, and so cut it down by a reducing valve to 90 pounds, quite unknown to the foreman in charge of the shop. All went well in the shop for weeks until one fatal day the engineer, in a burst of jocularity, related that he had reduced the steam-heating pressure to 90 pounds. Then did the black clouds of the foreman's wrath gather, and from the thunder and lightning of his blasphemy the engineer found shelter in a promise to immediately restore the 125 pounds steam pressure. Instead of doing so, however, the wily engineer "doctored" a steam gage to read 35 pounds fast. Putting this gage on the steam pipe in the shop indicated full boiler pressure therein; the foreman declared the temperature to be much higher than before and was appeased. Now when this issue of THE JOURNAL reaches the engineer it is safe to say that it will be confiscated lest it should fall into the hands of the shop foreman and create lasting enmity between them.

As a class, users of small steam powers are like our friend the shop foreman; they *think* they know, which is altogether different from knowing. As a class, furthermore, users of small steam powers know no more of the costs of producing their power than of the amount of power they are producing. In consequence they almost invariably underestimate both, and so they go on year after year, refusing to install the cheaper electric power for penny-wise reasons. These small units of from 10 to 100 horsepower or more aggregate a material proportion of the total mechanical energy consumed in any manufacturing locality, yet the manager of a transmission plant cannot regard them as probable customers with any degree of certainty. On the other hand, large power producers, such as electric lighting and railway systems and great manufacturing establishments, have, as a rule, made intelligent analyses of their power costs, and to them transmission managers must look as prospective consumers of considerable power. Of course the only valid commercial reason warranting such plants to change motive powers is to be found in cheaper production; and if the transmission manager can furnish power at a rate lower than the cost of its production on the spot, he may feel reasonably sure of supplying it. Great difficulty attends the making of forecasts of this nature, but it is hardly safe to believe that more than fifty per cent. of the steam power consumption of any locality may be relied upon as being certain to be displaced by transmitted electric power. In this event, more electric power is heading toward the region of the Bay of San Francisco than there is present demand for. This is a situation that our friend the wiseacre layman cannot grasp, for to his mind it is inconceivable stupidity, or at least unpardonable blundering, to embark capital into enterprises that do not insure immediate and large return upon every dollar invested.

Capital has exhausted every avenue for quick-return investments, and now perforce it must choose between

a meager two or three per cent. from banks or national bonds, and the five or six per cent. that may be brought in a few years from industrial enterprises—yes, "ventures," if you will have it so. Capital knows that it must *develop* avenues for investment, and hence it is that with clear, discerning judgment it gages the future by the past and invests in projects that give surest indications of eventual success. Capital chafes under idleness as does an athlete under indolence. It must reach out for investment as surely as the tradesman must reach out for business or as the mechanic for work. Failing to find investment, capital must make one, as surely as the professional man must make a clientele, before it will be satisfied. And that is exactly what capital is doing in these transmissions; it is making investments for itself by developing industries in every possible direction through the medium of providing cheap power for all purposes.

ELECTRIC PUMPING IN TULARE.

One of the most remarkable pumping installations being operated from electric power transmission lines in the world has been installed on the circuits of the Mount Whitney Power Co. for irrigation duty near the town of Exeter, Tulare county, Cal. This, coming at a time when electrically-driven pumps and pumping by electricity are receiving so much attention in the engineering world, is of great interest, in view of which the next issue of THE JOURNAL will contain an exhaustive technical description of the installation. The pump was built by W. T. Garratt & Co. of San Francisco, and, as the article will demonstrate, it alone is a very remarkable piece of engineering.

Gas

HIGH-PRESSURE GAS DISTRIBUTION.*

BY FREDERICK H. SHELTON.

FOR many years gas engineers have been steadily reducing both the operating and the investment costs necessary in the manufacturing department of the gas business. But if inquiry is made as to what material reduction of necessary investment, or what advance has been made in the department of distribution, it is difficult to point out anything very different from, or notably better than, the practice of twenty or even more years ago. While it is a compliment to the efficiency of standard gas distribution appliances that the inventive minds of many years have been unable to bring forth better forms, it is none the less a fact that, because of the continuation of settled forms and of a lack of improvement, the cost of our distribution system is to-day, for given volumes of business to be handled, practically as great as ever.

SOME ADVANTAGES OF HIGH PRESSURE.

Perhaps the most striking feature in the present practice of gas distribution is the extremely low pressure at which gas is delivered—average pressures of 2 to 6 inches water pressure equaling but a tenth or a fifth of one pound steam pressure. If customary pressures could be increased so that pipes of given size would deliver 10 to 15 times the volume of gas now handled, would it not enormously cheapen the cost of distributing systems? I have given this matter much thought for upwards of two years past, and some time ago reached the conclusion that illuminating gas could, just as well as not, be distributed satisfactorily at a number of pounds pressure, say from 10 to 30, instead of at but a small fraction of one pound, and that by such plan of working either present pipes could be made to handle several times the quantity of gas now delivered, or else that much smaller pipes would serve as well.

According to the formula of Pole, usually used in such matters, an 8-inch pipe four miles long, under present customary pressures of 6 or 8 inches, will deliver at the far end 8,000 to 9,500 cubic feet of gas per hour. Under a range of twenty to thirty pounds pressure, and operating as later described, by well accepted formulæ for the flow of gas of 0.650 gravity in such range of pressure, it could deliver 140,000 cubic feet per hour. A 2-inch pipe 1,000 yards long would deliver 650 to 750 cubic feet, compared with 4,600 cubic feet. A 12-inch pipe two miles long would deliver 33,000 to 38,000 cubic feet, compared with 550,000 cubic feet. To supply gas to a point 4½ miles distant at the rate of 10,000 cubic feet per hour, on present lines, in a recent instance figured upon, would have required a 10-inch pipe, costing about $26,000. With high pressure, however, a 3-inch pipe, costing but $10,000, gives equal capacity. To supply 15,000 cubic feet an hour at a point six miles distant, in another instance, required a 12-inch main at a cost of $40,000, while with high pressure, as hereinafter described, a main of but 4 inches diameter would have given the same capacity at a cost of $16,000.

I have recently had occasion to figure upon the construction of a distributing system, including 25 miles of pipe in the usual amounts of sizes, from 3 to 12 inches in diameter, the estimated cost of which was $82,000. The construction cost of a high pressure system in the same locality, with pipes ranging from 1½ to 4 inches in size, and including the extra cost of complete pumping equipment and consumers' house regulators, etc., was but $43,000, a saving of about 47 per cent.

INDIRECT PRECEDENTS.

This paper is more particularly directed to showing the feasibility of working at high pressure rather than to the figuring of savings to be made in assumed cases, each of which, whether real or imaginary, would differ from its neighbor, and would have to be figured upon its own conditions. I am assuming that the saving is so obvious, in a system that would make gas mains of a dozen times present capacity, that it is not the exact degree of gain to be made that may interest you so much as it is the manner of so operating, and the practicability of such a system. For on the one hand is an investment which, even after the cost of the unusual pumping machinery and high-pressure regulators and appliances are allowed for, is yet but a half of that ordinarily necessary; while on the other hand the increased operating expense of a high-pressure system—chiefly involved in the running of a moderate size gas compressing pump—is so slight as to only fractionally offset, and so small as not to begin to neutralize the advantage gained.

Illuminating gas, it should be remembered, is the only extensively handled commercial fluid that is delivered at a very low pressure. Water, steam, compressed air, natural gas, Pintsch gas, refrigerating fluids, etc., have been and are being widely distributed, sold or handled, for years in public places in several of the principal cities of the civilized world, and to such extent and in so many ways as to fully justify the statement that a number of pounds pressure in itself, in such matters, is neither unsafe nor infeasible. The mechanism and appliances for controling these various fluids, even at pressures up to several hundreds of pounds, have been well worked out into adequate and standard forms that fully serve the purposes of commercial industries. It is indeed curious that for so many years illuminating gas has continued to be distributed at but a small fraction of a pound pressure when all other liquids supplied by public companies are sent out usually at far greater pressures; and the universal tendency in such things is to increased tension. The reason for the continuance of low pressure with illuminating gas is no doubt the fact that relatively,

*Abstract of a paper read before the International Congress of Gas Engineers, Paris, France, September 3, 4 and 5, 1900.

and in the past, before the advent of any great volume of fuel business, the actual quantities of gas required to be handled have been small, and it has been found comparatively easy to provide pipes of sufficient size, and without undue cost, that would convey all the gas required. While such conditions have existed in the past, it is a question whether in the near future, for the reasons already stated, gas engineers will not find it both necessary and profitable to replace pipe diameter—convenient but expensive—by readily supplied pressure, to best distribute large volumes.

While some companies in the United States have slightly increased their pressures to increase the carrying capacity of their street mains, by the introduction of mechanical appliances, such as rotary blowers, to reinforce the pressure given by the gasholders, it has almost invariably been solely for the purpose of transmitting gas from one distributing point to another, and within pressures not exceeding 50 inches of water; and no general delivery of gas to the customer direct, and through all the mains at some pounds pressure, had been undertaken to my knowledge. The only instances among the 1,000 companies in the United States of which I have been able to learn wherein gas is being noticeably compressed, in connection with public supply or service, are as follows:

DIRECT PRECEDENTS.

In Louisville, coal gas has been pumped for about 2½ years by a piston compressor of about 30 by 36 inch cylinder size, at the rate of about 140,000 cubic feet per hour, through a 10-inch wrought-iron pipe, a distance of some 2¾ miles, for the purpose of filling outlying gasholders throwing a pressure of 10 inches. In this case no consumers are served along the line; no loss of candle-power has been observed. The initial pressure of 5 to 7 pounds is only that sufficient to overcome the friction of the pipe while filling the holder against 10 inches pressure at the rate per hour designated.

In Oakland, Cal., for about 10 years a mixed coal and water gas has been pumped by a piston compressor a distance of 8 miles, to Alameda, through an 8-inch cast-iron pipe with lead joints; also for the purpose of filling a gasholder at an outlying point. In this instance the initial pressure carried is 5 pounds; the terminal holder pressure is four inches. No individual consumers are taken off the line, although midway a governor controls a supply of gas taken from the main for the district of East Oakland. The loss of candle-power observed, due to compression, etc., is said to be slight, and not to exceed a quarter of a candle.

In Chicago for some years water gas has been pumped in the southern portion of the city from the plant of the Mutual Company's works, a distance of about 23,000 feet, through an 8-inch pipe line, for the purpose of filling an outlying holder. In this instance a rotary exhauster is used, giving an initial pressure of 10 pounds, and passing gas at the rate of about 60,000 cubic feet per hour into the holder against a pressure of 7½ inches. No consumers are taken off *en route*.

In Danbury, Conn., for 10 years past a 35-candle-power oil-water-gas has been pumped, under 40 pounds pressure, through a 2-inch wrought-iron pipe by a piston compressor a distance of 3 miles into stationary wrought-iron tanks. From these tanks the gas, controlled by a suitable governor, is supplied to the small town of Bethel, at customary low pressure. No consumers are taken off *en route;* and no loss of candle power is observed.

REQUIREMENTS OF HIGH-PRESSURE DISTRIBUTION.

It is clear that the satisfactory distribution of gas direct from the gas works to consumers at some pounds pressure, in order that they may be safely and well served through mains much smaller than the ordinary, would specifically require:

1. Straight mains of long life, with joints originally made tight and that will stay tight.

2. Machinery for compressing and pumping in which the likelihood of breaking down is remote.

3. Regulating main governors, reliable in character, for reducing the pressure of the high-pressure line to any desired low (ordinary) pressure in any given district.

4. Individual house governors, reliable in character, to enable the supply of customers anywhere along the high-pressure line.

5. Adequate safety appliances, so that in the possible event of any pressure regulating mechanism failing to work no damage can result other than the loss of gas.

6. Means for safely and easily putting in additional service pipes at any time on the high-pressure pipes while under pressure, without shutting off the supply to existing customers.

7. Freedom from loss of candle-power to any serious extent because of the compression.

Without consuming time unnecessarily by the relation of the detail of extended investigation, I became, and am, convinced:

First, that in the high-pressure gas work, wrought iron screw pipe, well coated against corrosion and carefully laid, will afford a practically tight system of gas mains and will last in most situations sufficiently well. The experience of 10 to 15 years of the natural gas companies, and others in the United States, with wrought-iron pipe gives warrant for this conclusion.

Second, that the standard types of air compressors, built to withstand severe usage in distant mining districts, are, with slight modifications, entirely suitable for pumping gas at some pounds pressure, are practically free from and are no more liable to breakdowns than are ordinary steam engines, and can be installed in duplicate at such moderate cost as to completely cover the fullest requirements of safety and insurance of supply. The thousands of air compressors in use throughout the world, as well as the many Pintsch compressing stations, give full warrant for this conclusion.

Third, that the district governors and regulators used for years in the natural gas fields in the United States will control any volume of illuminating gas from and to any range of given and desired pressure, and are so modest in cost, simple in form, and so compact as to enable their ready arrangement in duplicate, giving ample opportunity for inspection, cleaning, adjustment, etc. The very extended and satisfactory experience with such regulators by natural gas companies gives warrant for this assumption.

Fourth, that the inexpensive individual house governors, also used throughout the natural gas districts with great reliance and satisfaction, will equally well serve with illuminating gas. These governors are practically the same in type as those used in the Pintsch system of car lighting in about 100,000 cars throughout the world, and for many years with an almost entire absence of accident or trouble.

Fifth, that the use of simple forms of oil seals, or safety vents, will fully protect, as desired, either a district at large or one or more individual customers from danger or damage in the remote, though possible, event of a defective pressure regulating device working improperly. Such precaution is used in the natural gas fields, and is believed, and has so far been found, to give entire protection.

Sixth, that by the use of a saddle or lug bolted on to the gas main and a suitable pressure tapping device, service pipes can be easily added as desired without inserting a tee, interrupting the supply of gas, or increased expense, and with less danger and trouble than are involved in the present practice.

Seventh, that where high compression to, say, 200 pounds, would seriously affect the candle-power of the gas, compression to but 20 or 30 pounds—provided the gas is an ordinary coal gas or well-made water gas—will not decrease the candle-power visibly, or over the fraction of a candle, or enough to be an objection commercially.

Having satisfied myself upon each of the points as above, fully and in general, that illuminating gas could, with proper equipment, be readily distributed at 20 pounds pressure, and an opportunity offering within the past year, demonstration was made of my belief.

A PRACTICAL TRIAL.

The towns of Phœnixville and Royersford, 28 miles from Philadelphia, are about 5 miles apart, and together contain about 16,000 people. Each of these towns has had a gas company

for many years. Both of these companies were purchased last summer by the Consolidated Schuylkill Gas Company, controlled by myself and some associates. It was decided to lay a high-pressure connecting main from one to the other in order that the operation of the smaller gas plant could be discontinued and all gas-making be centered at one point. Between the two stations a 3-inch wrought-iron pipe, 23,015 feet in length, was laid, especial care being taken in the making of the joints and the testing throughout. When finished it was tight under 60 pounds pressure. The pipe was laid about 3½ to 4 feet deep along the line of a moderately hilly country road. At the far end of the line two regulators or governors, set tandem, are used to reduce the varying pressure of several pounds in the pipe line to that desired in the low-pressure existing mains, namely, a uniform 2.7 inches. The first governor is adjusted to reduce any pressure ranging up to 50 pounds down to 1 pound, and the second governor, more sensitive in action, is set to reduce the gas at 1 pound to the 2.7 inches named; both governors are of the non-freezing, dry diaphragm type.

For the first two months a small gasholder at Royersford was used in connection with the pipe line to insure the safety of supply and until it was felt that the system, as as a whole, was in complete running order. That condition being reached within that period, the gasholder was then shut off, and since that time the town has been served with its illuminating gas direct from the high-pressure main through the regulators, from a point nearly 5 miles away and without the use of a hoider or storage receptacle. It is my understanding that this is the first instance of this being done. The gas served is an ordinary illuminating gas of about 20 to 22 candle-power, made from naphtha. The general apparatus is an old one of inferior design, the superheating capacity being much less than it should be, with the result that the gas made is but partially "fixed." Under these conditions it would be expected that the compression would result in considerably reducing the candle-power by the throwing down of the unfixed illuminants. No particular depreciation in candle-power, however, has been observed, the gas at the far end of the line being, generally speaking, of good commercial quality and of practically the same grade as that delivered at the starting point. While variations in candle-power have been noticed, they are due to irrregularity in the quality of gas made in, and because of the poor machine so far necessarily used, and not to the fact of compression.

The gas pump has a capacity of about 100,000 cubic feet per day, at a speed but 75 per cent. of its rated speed. As this quantity of gas, however, is as yet not required, it has been found the most desriable plan to operate it for from 30 to 45 minutes every two hours or so, pumping and storing gas in the pipe line to a pressure of 25 pounds, and letting that gas furnish the supply until the pressure falls to 5 pounds, when pumping is resumed. The temperature of the gas is increased by the compression to about 120° F.

The volume of drip or condensation removed from the pipe line is abont one-eighth of a gallon per 1,000 cubic feet. The loss of pressure, due to friction in the pipe line, is from 2 to 3 pounds. While the general capacity at present is about 4,000 cubic feet per hour, by increasing the speed, governor adjustment, etc., and by the use of a larger pump, the line will handle two or three times the amount in the future, if desired. Along the high-pressure pipe line a number of customers are served by means of individual house regulators, reducing the pipe line pressure, whatever it may be, to 1.7 inches water pressure. One regulator controls but a single lamp post; another a large county almshouse; a third a run of 800 feet of pipe, serving about 17 houses; a fourth the lighting of a bridge. All of these regulators have worked satisfactorily continuously.

The operation of the system has been so continuously and so generally satisfactory that the owners of the company have decided to duplicate it on a much larger scale in the extensive suburban districts of Darby and vicinity immediately adjoining the city of Philadelphia. Work is under way in the district upon an initial system of about 22 miles of high-pressure pipe. The trunk line from the gas works is 6 inches in size and extends to a point 3 miles distant, and from that point two lines of 3 and 4 inch pipe further extend respectively to points 7 and 8 miles away from the gas works. The owners also of the River Shore Gas Company, serving gas in several small towns not far from Philadelphia, in the State of New Jersey, are now completing, under my supervision, a pipe line for the purpose of transmitting gas from their works at Riverton to the town of Moorestown, about 4½ miles distant. This equipment is almost identical with that at Phœnixville.

THE EQUIPMENT OF A HIGH-PRESSURE LINE.

The equipment of high-pressure lines, as above, with the accompanying minor parts, either necessary or desirable, may be conveniently divided into three principal parts, as below:

The compressing machinery (in duplicate), including a continuous steam supply, water jacket, speed and pressure governing mechanism, recording pressure gages, thermometers, low-pressure safety alarms, pulsation and condensing tank, meter.

The pipe line, including the matters of coating, joints, testing, drips, valves, service saddles, house pressure regulators, high-pressure house meters, individual house safety appliances.

Main line regulators (in duplicate) and terminal station, including indicating gages, recording pressure gages, thermometers, test lights, purge and vent facilities, photometer, safety seals (main line) high and low pressure alarms, by-passes, etc.

[Mr. Shelton's paper, which appears almost in full in *The Gas World*, London (Vol. XXXIII, page 356, Sept. 8, 1900), and in *The American Gas Light Journal*, New York (Vol. LXXIII, page 526, Oct. 1, 1900), describes the principal items above listed in such a manner as to convey a fair idea of the machinery used by Mr. Shelton and associates in the United States for high-pressure illuminating gas distribution.—THE EDITOR.]

Metallurgy

ELECTRIC FURNACES.*

BY M. KELLER.

ONE may take as archetypes of all modern electric furnaces those of Siemens & Halske and of Moissan. The first of these consisted of a crucible of some refractory earth, receiving current at its base, a movable carbon pencil fixed within it acting as the second electrode. The arc was thus formed between the lower point of this carbon electrode and the surface of the materials contained within the crucible. The Moissan furnace consisted of a block of lime, hollowed out at its center to receive the materials to be heated, and provided with horizontal channels for reception of the two carbon pencils conveying the current. A second block of lime, fitting over the first, completed this furnace, and served to retain the heat emitted by the arc which formed between the points of the two carbon pencils when the electric current was passed along them. The materials in this furnace were placed in the hollow cavity in the center of the block and the arc played *over* their surface.

The first of the electric furnaces developed from the above laboratory types for industrial purposes was that of the brothers Cowles. In this furnace the material to be treated was placed between two conducting surfaces which conveyed the current, and was surrounded by non-conducting, finely-divided material. The current was thus obliged to traverse the material lying between the two electrodes, and if this in the unfused state was a non-conductor of electricity, movable carbon electrodes were used in order to form an arc above the furnace contents and bring them to the fused condition. This furnace, invented in 1885 and improved in 1887, was used at Milton in Staffordshire for reduction of aluminum oxide, and for production of aluminum alloys.

*Abstract of a paper read before the International Electricity Congress at Paris, July, 1900.

The Héroult furnace introduced at a later date for obtaining alloys of aluminum with copper, was based upon the same principle as that of the Cowles brothers. This furnace has been used at Froges and at Neuhausen for production of aluminum, and more recently for the production of calcium carbide. The modified form adopted for the latter manufacture consists of a box mounted upon wheels, the base of which is of carbon and the sides of some non-conducting material. The base of this box acts as one electrode, and a carbon rod, subject to a vertical up-and-down movement, forms the second. The furnace body is thus movable and can be wheeled away when the reaction is completed in order to be replaced by a newly-charged one.

We may conveniently classify the furnaces designed for calcium carbide manufacture as: (1) Arc furnaces (based on the Moissan and Siemens type); (2) Resistance furnaces (based on the Héroult type); (3) Incandescence furnaces (based on the Cowles type).

Arc furnaces may be again subdivided into three classes, according to the mobility of one or both electrodes and the number of carbons used. The furnaces designed by Patin, by the Deutsche Gold und Silberscheide Anstalt, and by Street, have both electrodes movable, and thus come under subdivision I.

A very large number of furnaces fall into the second group, having one electrode fixed—generally as hearth or floor of the furnace. The furnaces exhibited by the Société des Carbures Métalliques at the Exhibition, and those designed by Siemens & Halske, Schuckert, and other well-known firms for carbide production, are of this type.

To the third subdivision belong all forms of the multiple arc furnace, which has lately become much used, because it enables the area of arc heating to be greatly extended. The Gin and Leleux, Bertolus, Memmo, Nicolai, and Bovy furnaces are leading examples of this type. In most of these furnaces the floor of the furnace acts as the common secondary electrode for the arcs which form between it and the three or more primary electrodes fixed around it. Polyphase currents are generally used with these furnaces.

In all arc furnaces the temperature attained varies with the intensity of the current used, but as in any case the temperature of the arc is very high and considerably above that required, loss of energy follows from arc heating in carbide production. There is also considerable loss of material owing to the finer material charged being carried away by the "blowing" of the furnace. For these and other reasons arc furnaces are not suitable for carbide production.

CLASS II.

Resistance furnaces resemble in form and construction arc furnaces, but they work with a lower electromotive force, as the materials charged into the furnace body act as intermediate conductor between the two terminal carbons. The work done can be calculated by aid of the Joule formula $W = RI^2$, and the temperature attained is directly related to the sectional area of the electrodes. In this type of furnace the fusion of the materials is tranquil, and is unaccompanied by violent evolutions of gas. For carbide production an electromotive force of 20 volts to 25 volts suffices, but heavier currents are requisite than with the arc furnaces, and conductors of larger sectional area must therefore be provided. The new furnace of the Compagnie Electrométallurgique des Procedés Gin and Leleux is of this type, and is employed in a large number of carbide works.

In the third class of furnace—incandescence furnaces—the intermediate conductor between the ends of the two electrodes is formed by a succession of small pieces of coke or other form of carbon. The passage of the current causes this bed of coke to attain a high temperature, and the materials placed upon it or mixed with it in their turn are raised to the same temperature. This type of furnace permits the utilization within a limited area of the greatest amount of energy, and avoids the grave defect of the second type, namely, that the currents must always traverse the whole depth of the layer of materials already fused.

It is well to now pass on to consider electric furnaces under another classification, namely, that of the kind of current employed. Furnaces using continuous current have been sometimes called electrolytic furnaces, because in these not only thermal but chemical effects may be produced. Alternating current furnaces have latterly been widely adopted, because the dynamos yielding monophase or polyphase currents are better adapted to stand the resistance variations incidental to electric furnace operations.

The furnaces employing monophase currents are best arranged in series, for in this case it is possible to utilize a higher electromotive force and to save copper in the necessary leads. If, however, arc-heating is being employed, it is better to connect the furnaces in parallel.

Bertolus, in 1897, was one of the first to patent the application of polyphase currents to furnace work. In the furnace designed by Bertolus tri-phase current was used, and three carbon electrodes were connected to the three terminals of the dynamo, while the hearth of the furnace itself provided the common return electrode. In later forms, the three different phases of the current have been utilized in separate furnaces, and these therefore each operate as though worked with monophase current.

ELECTRODES.

The difficulty of obtaining carbon electrodes of suitable size and length has for a long time hindered the increase of the size of the furnaces. Engineers have, however, given much attention to this question, which for the carbide industry is of considerable economic importance.

For those furnaces in which vertical electrodes are used, the carbon is generally formed square or rectangular in section, and undergoes special treatment in order to increase its conductivity, while for the other types of furnace carbons are usually made round.

In order to protect the carbon at the point where it entered the furnace, it was at one time customary to use water for cooling purposes, but this proved dangerous, and it has been given up for cold air, or some form of protecting composition.

REGULATING THE ELECTRIC CURRENT.

In the modern forms of furnace for carbide production, working with relatively low electromotive forces, it is usual to find currents of 8000 amperes to 10,000 amperes employed. With such currents it is impossible to use ordinary cut-outs, and it is customary to make the movable electrode of the furnace act as circuit breaker. On account of the accidents which may occur to the dynamo, steam engine, or turbine when a single furnace is worked in this manner on an electric circuit, it is advisable to work several furnaces in parallel from the one dynamo.

CURRENT PRESSURE.

The electromotive force required in arc furnaces varies greatly, and depends upon the conductivity of the gases which are emitted from the heated substances. In the manufacture of carbide of calcium an electromotive force of 50 volts to 60 volts is required; in that of corrundum 50 volts suffices, while the electrothermal method for production of iron only requires only 20 volts.

In resistance furnaces a lower electromotive force is generally sufficient, and carbide of calcium can be manufactured in the Héroult type of furnace with a current of only 25 volts pressure. Aluminum can be produced in the same furnace with a pressure of from 20 to 25 volts.

The third type of furnace—"incandescence furnace"—can work with practically any electromotive force up to 80 or 100 volts, for the resistance increases with the increase of the length of the bed of materials through which the current has to pass, and this may be varied at will.

CURRENT.

In the Cowles type of furnace currents of 5000 amperes at 50 to 60 volts have been used. In the Héroult furnace currents of 6000 amperes are used. For carbide production it is more customary to use currents of from 1000 to 2500 amperes with single pairs of electrodes, but where several pairs of electrodes are used for arc heating in the same furnace, this current may be doubled, trebled or quadrupled. Furnaces with a single arc and one movable

electrode are, however, now being worked with currents of 5000 to 6000 amperes. The Gin and Leleux type of resistance furnace can be worked with currents up to 10,000 amperes, and the same amount of current can be utilized in the incandescence furnace, which, working with a higher electromotive force than the resistance furnace is able to utilize for thermal purposes, no less than 1000 kilowatts electrical energy.

DEVELOPMENTS OF THE ELECTRIC FURNACE INDUSTRY.

Recent estimates have placed the total energy employed in electric furnace operations at 230,000 horsepower, of which total calcium carbide accounts for 185,000 horsepower, aluminum for 27,000 horsepower, copper for 11,000 horsepower, and carborundum for 2000 horsepower. In France alone it is estimated that 60,000 horsepower are employed in the carbide manufacture; while the production of phosphorus, vanadium and ferro-chromium are more recent thermo-chemical industries started in Savoy.

The improvements made in electric furnaces in recent years have resulted in a greatly improved output of carbide per kilowatt hour, and in the latest form of the Gin and Leleux furnace it is now possible to obtain 6.20 kilogrammes carbide per kilowatt day of 24 hours. This corresponds to a thermal efficiency of 75 per cent.

The paper closes with a few details concerning the electric furnaces which are exhibited in the electro-chemical section of the exhibition. Three of these are shown in operation, and comprise a Moissan furnace, a Bullier furnace, and a small model of the Gin and Leleux type of furnace. The first consumes 40 kilowatts and the second and third 70 kilowatts electrical energy when in operation.

THE SIEMENS-HALSKE CYANIDE PROCESS.

BY JOHN B. C. KERSHAW, F. I. C.

THE Siemens & Halske process for recovering the gold from the liquors obtained by the treatment of the crushed ore, or the tailings, with dilute potassium cyanide solution is rapidly making headway, and its application to the solutions resulting from a still more modern process for successfully leaching slimes with cyanide is calculated to further extend its field of usefulness.

Although this process is not being worked upon an industrial scale of operations, to the writer's knowledge, in any European country, yet as the whole of the preliminary work was done in Germany, the process is founded upon an observation made by one of the heads of the firm of Siemens & Halske in the year 1887 when performing some experiments upon the electro-deposition of gold. It was perfected so far as laboratory experiments permitted in Berlin between that year and the year 1893, when arrangements were made to have the process upon a fairly large scale in the Rand district of South Africa. A plant capable of treating 100 tons of tailings daily was erected at the Worcester works of the Rand Central Ore Reduction Company. This installation was a complete success, and the progress since that date has been remarkably rapid. The last report issued by the directors and manager of the Rand Central Ore Reduction Company contains a list of thirteen mines where the Siemens & Halske recovery process is now in operation, with an aggregate monthly capacity of over 73,000 tons.

In addition to these thirteen mines, the process will shortly be at work at eighteen others where the plants are under course of erection. If these figures are trustworthy the process has therefore evidently gone to South Africa to stay, and if the policy of the Rand Central Ore Reduction Company is continued by the new company which has assumed the control of the patent rights in South Africa, it would only appear to be a question of years before the old zinc-box method of recovery is entirely displaced.

The Siemens & Halske process depends upon the deposition of the gold from very weak cyanide solutions by means of an electric current of feeble intensity. The two difficulties that had to be overcome in designing a suitable depositing vat for the conduct of this operation arose, the one from the activity of the cyanogen gas liberated at the anode, and the other from the extreme dilution and poverty in gold of the solution requiring electrolysis. Nor was the selection of a material for the cathodes an easy matter, as gold, the most suitable metal, was excluded by its high cost. Carbon, the usual anode material, could not be used because it disintegrated easily in the solution and the contamination of the effluent with finely divided particles of carbon led to difficulties in leaching. After many experiments with different materials Messrs. Siemens & Halske selected iron—the cheapest metal—as anode material, and thin sheets of lead as cathodes to receive the deposit of gold.

The difficulty of extreme dilution was overcome by causing the electrolyte to pass between several hundred pairs of electrodes before issuing finally from the last of the depositing vats. Further, no attempt was made to remove the whole of the gold from the cyanide solution, the continual return of the effluent to the leaching vats rendering a complete extraction of gold unnecessary. The action of the cyanogen upon the anodes of course leads to their solution and to the formation of cyanides of iron and prussian blue. As iron is cheap, this loss of iron does not very greatly add to the cost of the process. It is stated that the lead cathodes are allowed to remain in the vat until they are coated with an amount of gold equal to from 2 per cent. to 10 per cent. of their weight, but the figures quoted below show that this proportion is not attained in practice. The lead is then removed from the vat, and is cupelled in order to recover fine bullion.

In the Rand district the cupellation of the lead bullion is undertaken by the Rand Central Ore Reduction Company, who buy all the lead bullion from the companies using the Siemens & Halske recovery process on its assay value, and thus enable these companies to dispose of their product on advantageous terms in the vicinity. The weight of auriferous lead purchased in this manner in the Rand district during the twelve months ending June, 1897, was 2,409,130 ounces; the weight of fine gold obtained from this on cupellation was 31,588 ounces, valued at £116,875. The Rand Ore Reduction Company also cupelled 1,580,772 ounces lead bullion for other companies in the same period, and produced therefrom 57,994 ounces of gold, valued at £214,577. Working out the mean per cent. of gold contained in these two aggregate weights of lead bullion, we find in the former case it amounts to only 1.3 per cent., while in the latter case it amounts to 3.6 per cent. The report does not clearly indicate the origin of the greater of the two aggregate weights of lead bullion, and it is possible that it was obtained from works using non-electrolytic processes.

The only description of the actual plant at the mines used for operating the Siemens & Halske process that has yet come under the writer's notice is contained in a paper read by A. von Gernet before the Chemical and Metallurgical Society of South Africa in 1895. This paper gives details of the plant erected at the Worcester works of the Rand Central Ore Reduction Company for the treatment of 3,000 tons tailings per month, or 100 tons per day. Four electrolytic vats were used, each 70 feet long by 8 feet wide and 4 feet deep. The anodes were plates of iron 7 by 3 feet and ⅛ inch thick, so arranged in the vat that the solution was compelled to take a vertically zigzag course in its passage from one end to the other. Slips of wood along the sides and bottom of the vat held these anodes in the required vertical positions; 1086 pounds of iron were used per month for anodes. The plates were enclosed in coarse canvas bags, in order to retain the prussian blue and to prevent short circuiting. The thin sheets of lead used as cathodes were stretched in wooden frames and suspended between the anodes.

Calculation leads one to assume that the number of pairs of electrodes in each vat at Worcester was 71, spaced about 1½ inches apart. An electromotive force of 4 volts was sufficient to yield a current of .05 ampere per square foot at this distance. A current of 600 amperes was passed through the four vats, the electrodes being coupled in parallel, not in series. An energy consumption of about 3½ electrical horsepower was therefore theoretically required to operate the process; in practice an

engine of 5 electrical horsepower was found to be fully adequate. In the Worcester plant a cathode surface area of 3,000 square feet per vat was obtained, since both sides of the lead sheets functioned as cathodes. The vats were covered and locked, and only required opening about once a month for removal of the gold-coated lead and for insertion of new lead cathodes in place of those removed. The consumption of lead was about 750 pounds monthly, and was valued at 1½d. per ton of tailings.

Two estimates of the working cost of this process, both by A. von Gernat, one made in 1894 (A) and the other in 1896 (B), are given below. These estimates include the cost of cyaniding, but not those of cupellation; and no allowance is made for royalty charges or for interest and depreciation charges on the electrical plant and machinery. These charges will, however, be small. The estimate A is for a plant with a capacity of 100 tons tailings per day, while B is for one capable of treating 500 tons daily. The items are expressed in dollars per ton of tailings treated:

	A.	B.
Filling and discharging	$.200	$.200
Cyanide	.120	.068
Lime	.024	.010
Caustic soda	.010	....
Lead	.022	.030
Iron	.044	.006
Labor—white	.104	.100
Labor—native	.038	.038
Coals	.092	.080
Stores and general charges	.064	.064
	$ 718	$.696

When the working costs of the older zinc box process of recovery are compared with those just given, the gain in economy by the use of the Siemens & Halske process is seen to be considerable. Rose* states that the cost varies from $.720 to $.240 per ton according to the local conditions, the average being about $.960, while Eissler† states that the costs are about $1.72 per ton tailings treated; the gain in the case of the S. & H. process is partly due to a saving in cyanide, and partly to the greater convenience and simplicity of the monthly cleaning-up process.

The former results from the weaker solutions of cyanide used for leaching the tailings. Weaker solutions, however, signify that greater time must be given to the leaching operation, and the exact point at which the value of the saved cyanide no longer balances the value of the extra time is by no means easy to determine, and differs for each locality and works. The relative advantages of the two processes in the Transvaal are further complicated by the fact that only one of the processes is covered by valid patents, and requires the payment of a royalty for its use. The decision of the Rand Court in the great trial of last year has rendered the McArthur Forest process a free process in the Transvaal, and the extension of the electrolytic recovery process under these conditions is a striking testimony to its worth. The future progress of the electrolytic recovery process will, therefore, depend very largely upon the policy pursued with regard to royalty charges. These have recently been reduced from 3 per cent. to 2 per cent., and it is intended as the use of the process continues to extend to reduce them still further.

The Transvaal patent rights have lately passed under the control of a new company, the Gold Patents Company, Ltd., with a nominal capital of $600,000. The Rand Central Ore Reduction Company, Ltd., and Messrs. Siemens & Halske of Berlin have each received $240,000 of shares in the new company as the equivalent of their interest in the process, and the remaining $120,000 of shares has been taken up by local financiers.

In concluding this brief review of one of the most successful electro-chemical processes, it may be pointed out that somewhat similar processes have been patented and worked in the United States by Eltonhead & Langhimer. The process worked by the latter at the works of the Wyandotte Mining Company in Washington, Alabama, would appear to have been exactly the same as that of Siemens & Halske, but the writer is not aware whether it is still in operation.

The Siemens & Halske method of gold recovery, successful as it has been, cannot be regarded as perfect. Neither the anodes nor the cathodes answer the requirements of a perfectly satisfactory process. Any improvements that occur may, therefore, be expected to concern these, and the iron and the lead may be replaced by metals or materials of a more durable character.

*"The Metallurgy of Gold," Dr. T. K Rose, London; Griffin & Co , 1896, p. 331.

†"The Cyanide Process," M. Eissler, London; Crosby, Lockwood & Co., 1895, p. 39.

Operation

THE INFLUENCES EXERTED BY POWER FACTOR.*

BY F. H. LEONARD, JR.

POWER factor is the ratio of the true watts to the apparent volt-amperes in an alternating-current conductor, circuit or device (Houston). In a direct-current circuit the energy is calculated by multiplying the volts by the amperes, and the result is the true energy in the circuit in watts, but in alternating-current circuits this does not follow, as the electromotive force wave is out of phase with the current wave in every case except when the load is purely non-inductive, as with a load consisting of incandescent lamps only. When arc lamps or induction motors are used there is always a lagging phase displacement of the current, and when synchronous motors are used there is also a phase displacement of the current which may be either leading or lagging behind the electromotive force wave, and both conditions may occur, in the case of the generator being driven by a steam engine, twice in each revolution.

With water power, a steam turbine or other prime mover where the angular velocity can be maintained practically uniform and where speed variations affecting the generator take place gradually in a period covering several revolutions of the generator, much better results can be obtained with synchronous motors, always of course presuming that the motor is designed to, and does in practice, give the same electromotive force wave as that produced in the generator, which for reasons which have been at length discussed by many able authors should be a sine curve. Power factor is comparatively a new term to the central-station manager, and, in fact, was hardly ever heard of before the introduction of the alternating-current motor, though some central-station superintendents had noticed that there was considerable current flowing in their primary circuits when all their transformers were running with open secondary circuit, and that this current did not take the energy from the steam engines corresponding with the volt-ampere readings. To express this condition the terms "false currents or wattless currents" were used.

The transformer when very lightly loaded or when running with open secondary takes much more apparent energy from the circuit than the real energy, because of the lag or phase displacement of the current wave. This displacement, however, grows constantly less as the load is increased, until the electromotive force and current waves nearly coincide. To illustrate this graphically, the two diagrams of electromotive force and current waves in a transformer in open circuit and under full load show that the instantaneous values of the product of volts and amperes must be less than the apparent watts, and must be multiplied by the power factor to represent the true energy. As will be noted, the maximum electromotive force occurs before the current has reached its maximum point. Referring to the full load curve, it will be seen that the current and electromotive force curves have nearly reached conditions where they increase and decrease together. The nearer this condition is approached the nearer the power factor approaches unity or 100 per cent. power factor.

As an induction motor is practically the same as a transformer with one of its elements in motion, its action with regard to power

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factor may be traced in the same manner, as explained in connection with a transformer. The primary circuit furnishing the magnetizing current or field and also the work current by induction to the secondary, when running light generates a counter electromotive force so high that only enough current is taken in the secondary to overcome the friction of the bearings. As load is added the speed is slightly reduced, the slip resulting in lowering the counter electromotive force until enough current is allowed to flow to do the added work. A very slight reduction in speed is sufficient to reduce the counter electromotive force of the secondary of the motor varying not to exceed five per cent. in speed fro n light to full load and usually not over two per cent. over the working range of load usually met with. These motors are self-starting from the alternating-current lines, and with suitable starting devices take about full load current for a few seconds in coming up to speed light, or a little more than full current in bringing up to speed their normal load, a somewhat longer time being occupied in reaching full speed, depending on the inertia and friction characteristics of the work. If you will consider the counter electromotive force of the motor secondary as the equivalent of resistance of the transformer secondary the similarity of action will be more striking. The synchronous motor differs from the induction motor from the fact that it does not make its own field, which is usually excited from a separate source of direct current, and it is not usually capable of starting itself even without load, but must be brought up to synchronous speed by means outside of itself. A small induction motor is generally supplied for the purpose, which is disconnected after the synchronous motor has been brought up to speed. The load is then applied gradually with a friction clutch coupling, friction pulley or equivalent device. Once in step, the synchronous motor cannot vary in speed, except the generator driving it changes speed, any more than though the two were positively coupled or mechanically geared together, except by overload much beyond the capacity of the motor, which breaks it out of step as though the gear were broken, and having fallen below speed even for a fraction of a second, it cannot recover, but will stall, in the meantime absorbing excessive current unless the circuit is immediately opened. The load must then be thrown off and the motor started again as at first. The fact that the synchronous motor has a separately excited field is an advantage under certain conditions, as pointed out in my paper before the National Electric Light Association at the New York meeting in 1895. By increasing the field excitation sufficiently in a synchronous motor the apparent paradox of a counter electromotive force higher than the line or impressed electromotive force is produced by the motor sufficient to raise the electromotive force of the line, overcoming all drop, and even altering the pressure at the generator itself, at the same time introducing leading currents having a condenser effect on the line which may be made to balance out the lagging currents produced by induction motors, arc lamps, etc. If this leading phase displacement can be made equal to the lagging phase displacement of other devices, a power factor of unity would result, as suggested by an eminent engineer, though in practice, during a period covering the whole history of this branch of the art, I I have never met such a condition, nor have any of my friends in the profession, many of whom have had extensive experience with synchronous and induction motors separately and both together on the same circuit.

An over-excited synchronous motor in the right place, with a load not subject to sudden variations and in charge of an attendant in communication with and controlled by the central-station chief, is a convenient means of overcoming line drop and poor power factor. Over-excitation should not be carried too far, as it will result in pumping or flickering the lights. I have a vivid recollection of a case in which a 2½-horsepower self-starting synchronous motor, which I designed, pumped the whole circuit on a 300-kilowatt alternator. Under a steady load and careful adjustment of the field excitation, a large synchronous motor supplied with current from a well-designed generator driven by water power or steam turbine, a power factor at full load of .94 or a fraction better may be obtained, though the same motor furnished with current from the same generator driven by a slow-speed reciprocating engine, would hardly attain a power factor of .90 at full load, as the fly wheel moment of the motor would make it difficult to follow the changes in angular velocity of the generator, the tendency to break out of step resulting in surges of current, as before intimated.

Generators directly connected to slow-speed reciprocating engines, in my opinion, are not suited for operating synchronous motors or rotary converters unless extreme care is taken in designing the fly wheel so as to obtain the minimum change of angular velocity per revolution. A much larger percentage of speed variation taking place more gradually, is less disastrous to the attainment of high-power factor.

The best load for a synchronous motor is one of uniformly steady character with no sudden changes in the work it has to do. Throwing the load off suddenly calls for instantaneous adjustment of field excitation in order to prevent sudden rise of electromotive force, which in a large motor would affect the whole line, and even change the voltage of the generator, having a disastrous effect on incandescent lamps that may happen to be in circuit. Suddenly adding a load to a synchronous motor has the reverse result and adjustment of the fields become immediately imperative to prevent heavy drop in electromotive force. A single synchronous motor subject to sudden load variations may easily defeat any attempt at good regulation on the part of the central-station management. These objectionable features are minimized, though never wholly overcome, by designing both generators and motor for exceptional regulation, using a distributed armature winding with a large number of slots per pole per phase. The old style armature with windings concentrated into a single slot per pole per phase are unsuited on account of their high armature reaction for this class of work.

The induction motor being complete in itself, requiring no exciter, starting motor or clutches, and furthermore, being automatic in its regulation without any special appliances, free from commutators or brushes, is simplicity itself; its essential features consisting of a stationary primary and a rotating secondary in large sizes when well designed has a power factor at full load of .94 or better, regulates well under sudden fluctuations of load without reflecting seriously on the line and generator, but in fact actually tending to assist the regulation of the line. A load thrown suddenly onto an induction motor immediately increases its power factor and helps the regulation of the generator supplying this sudden demand for current. As the power factor of the induction motor is low at light load, it follows that a sudden reduction of the load at once lowers the power factor of the motor, calling for lagging currents in the line, replacing by inductive drop the ohmic drop of the work current of the moment before the armature reactions in the generator tending to demagnetize its field and prevent increased electromotive force, which would otherwise result when load is thrown off. For varying loads and for operating incandescent lamps in connection with a power circuit, under the ordinary commercial conditions, the preference is altogether in favor of a well-designed induction motor. With a secondary consisting of copper bars secured to short circulating rings at both ends, insulation is never troublesome, and in fact may be omitted entirely. It rotates without electrical contacts or connections inside the stationary primary element which can be safely insulated for all ordinary voltages, and in the larger sizes connecting the 2000 volts pressure directly to the motor terminals. In the small sizes it is of course advisable to use transformers to reduce the pressure to 500 volts or less where subject to careless handling. Having once become familiar with them, you would never think of using direct-current motors with their troublesome commutators and brushes and expensive repair accounts. Intelligent selection of the size of an induction motor for the work it has to do has a very important influence on the power factor of the line, and it should not run with an average load much below its rated capacity. It is much better to select the motor which, being loaded to its rated capacity, or nearly so,

operates with a high-power factor and can be overloaded for short intervals to the extent of 25 per cent. of its capacity without doing any harm; as there are no delicate parts to this type of machine, nor any moving insulated wires, they will stand a much higher temperature without deterioration than the equivalent direct-current motor. Induction motors are also designed for variable speed, many now being used for crane work and other uses calling for variable speed and torque, but in this class of work they are hardly equal to the direct-current series motor, and unless very expensively designed, operate with low efficiency and power factor, though where non-inductive resistance is used for control the power factor may be improved at the expense of efficiency.

Arc lamps have been until recently operated from direct-current series dynamos, though the first important arc lamp installation used in the city of London, England, the Jablochkoff candles, as they were called, were operated by alternating-current dynamos. Several years ago the direct-current incandescent companies realized the advantage of being able to supply arc lamps from their incandescent circuits and adopted the direct-current incandescent open arcs. These were soon followed by the enclosed arcs, which, operating at a higher voltage, admitted of individual control without excessive waste in the large resistance required with the open arcs. Besides this, a great saving was realized in the amount of carbon burned, the inner globes preventing access of oxygen which rapidly disintegrates and causes the carbons to waste away. By no means the least saving which followed was the was the reduced labor, one man easily trimming six times as many enclosed arcs as he could of the open arcs, as they required attention once in several days instead of daily trimming.

From the direct-current enclosed arc it was but a step to the alternating-current enclosed arc with resistance in series, or with auto-transformers or choke coils on commercial alternating-current incandescent circuits. It was found, however, that the alternating-current arcs operated to reduce the power factor of lines with which they were connected, depending on the regulating device used in connection with them, it being practically impossible to obtain a satisfactory light without some regulating arrangement, though sometimes sufficient choking effect is produced by the feed regulating magnets. All such regulating arrangements reduce the power factor except the resistance method; but the resistance, while improving the power factor, wastes true energy and reduces the efficiency, while the inductive regulators only increase the apparent energy or wattless currents. The advantage of operating arc and incandescent lamps from the same dynamo simplifies the central-station equipment and admits of the use of a single type of dynamo for all purposes of higher efficiency, interchangeable parts, one type of reserve apparatus, and easier switchboard control. Some of the best inventive talent on the continent has recently been employed upon devices to enable the central-station management to rid themselves of the direct-current series arc dynamos, which at best occupy much floor space for their output and have a maximum efficiency of 75 to 80 per cent. as against an efficiency of 90 to 97 per cent. in large, modern alternating-current dynamos which occupy the minimum floor space per unit of output at much lower first cost. For alternating-current street lighting with lamps in series, one device has followed another till we now have an almost bewildering variety, each device having its superior points, making the choice more difficult.

The constant-current transformer operating a string of arcs is almost perfectly automatic, provided the load is not too much reduced and can be tapped onto any part of the line to economize wire, the device itself being located in a small sub-station which may consist of an underground vault, as inspection and adjustment are not frequently necessary. This arrangement has a very fair power factor at full load, but the power factor is low when partly loaded. A device operating on the choke coil principle has all the advantages named in connection with the first arrangement. The amount of choking effect is regulated by the number of lights which is desired to compensate for. If a small percentage of regulation is required, a small regulator at low first cost is sufficient, and at full load the power factor is high, the inductive effect depending almost entirely upon the lamps themselves. Another arrangement has been designed on the principle of the constant potential transformer with loops taken out to automatically vary the voltage as lamps are turned off or on. The power factor is good and rather better at light load than the others, but such a regulator should be kept in the central station, or in a sub-station when it has the advantage of an intelligent attendant.

Besides devices of the above types, individual transformers may be used, but their high first cost and the fact that each lamp must be turned on and off individually instead of in groups as with the previously mentioned apparatus, makes their use impractical for street lighting except under special circumstances.

In some notable cases where central stations are using power transmitted from a distance, induction or synchronous motors have been coupled direct to direct-current arc dynamos; this would be the ideal place to use a synchronous motor immediately under control of the central station if the induction motor load occurred at the same time, but unfortunately they occur at different periods and we can see no reason for using the synchronous motor, as the induction motor is self-starting and requires no separate excitation. In any case the motor-driven arc dynamos are out of the question except where the frequency is too low for satisfactory arc lighting. Arc lamps are very unsatisfactory on 25 cycles and their effect at least unpleasant unless the frequency is in excess of 35 or 40 cycles. With a mixed lighting and motor load there should be no difficulty in getting a line power factor of .90, and with load consisting mainly of motors .80 to .85. I have in mind a case where about 3,000 horsepower, in motors ranging from fan motors to motors of 500 horsepower, are used, and recently measurements showed a power factor of about .90, the percentage of incandescent lamps on the circuit being almost inappreciable.

A power factor of .80 at full load would be disastrous to the regulation of the old-style single-phase dynamo; no amount of excitation would enable them to hold the voltage on the line. Though many will no doubt recollect seeing at the World's Fair at Chicago in 1893, the then monster two-phase dynamos, which were but two large alternators with armature mechanically coupled together so as to give the proper phase displacement to the two independent circuits. Some Canadian water-power stations which have not yet installed polyphase apparatus having two single-phase alternators, might adopt this expedient for obtaining two-phase currents to start a power circuit. With ample water power, the added expense for a day circuit would not amount to much, probably little more than the cost of an additional attendant which would easily be covered by a contract for furnishing power to some manufacturing establishment, or perhaps pumping water for the city and neighboring villages. The power business once started would grow rapidly and become an important source of revenue. Few realize the extent to which the power business is destined to grow. The old-style alternator will stand a moderate amount of motor load mixed with lighting load, but when the motor load becomes a large percentage of the total load, the old dynamos which perhaps were admirably adapted for supplying incandescent lights will no longer be suitable. The growth of the motor business has called for radical changes in the design of alternators. Machines which on short circuit would give double full-load current were the rule, and this was even urged as a distinct advantage in such an emergency. For motor work, the inherent regulation indicated by a short circuit current of at least three or four times full-load current is demanded, and a change of excitation with full load current and .80 power factor not exceeding 15 or 20 per cent. and capacity for 25 per cent. more than normal full-load current for six hours without dangerous heating, or 50 per cent. more than full-load current for one hour, which means a very superior dynamo.

This state of perfection having been reached through gradual evolutions resulting from the difficulty of maintaining regulation with motor loads and lagging currents, which tend to demagnetize the fields and lower the voltage, the lagging currents call for

increased capacity in the dynamo line and transformers, which supply current to the phase displacing devices, though the power is not increased beyond the small amount necessary to supply the I. R. losses in the copper. This calls for increased investment to cover the first cost of the improved dynamo transformer and added copper, though notwithstanding the advance in raw materials, the very superior dynamos of to-day cost no more than the dynamos of a few years ago, and not so much per kilowatt as we were obliged to pay ten years ago for the old single-phase dynamos. In all classes of business it is poor policy to attempt to save on the first cost of a plant by buying machinery which is out of date. This is particularly the the case in making an investment in electrical apparatus, the design of which has been undergoing such active gymnastics in the past ten years. We must look well into the future and anticipate the growth of the power business, which already bids fair to outstrip the lighting, and get only the best apparatus well up to date in every particular. The apparatus made by the leading electrical manufacturers on intelligent specifications more nearly approaches perfection than any other power-translating device, notwithstanding the comparative youth of the art. What engine or water wheel builder would for a moment consider a specification calling for 96 per cent. efficiency? Yet electrical manufacturers for the larger sizes of dynamos will guarantee even better than such efficiencies.

With these high attainments it is hard to conceive of any material improvement in electrical apparatus, and we shall probably see little more of the changes once so frequent where entire plants were consigned to the scrap heap because it was cheaper to buy new than to continue for a short time the operation of the old, the difference being sufficient to turn the balance between success or failure of the enterprise. Already the process of standardization of things electrical has set in, and we may look for changes in the future tending to a reduction to well-recognized standards in construction of apparatus and central-station practice rather than to startling improvements in design.

Power factor, which at one time was the great bugaboo of the electric central station, is now being rationally met and provided for in the equipment of power houses as a necessary evil and one of the incidental expenses of a new branch of the business, which adds materially to the income of the plant and enables the hard-working manager and superintendent to please his stockholders with increased dividends.

OPERATING WORK AS A FEATURE OF TRAINING.*

BY WM. S. ALDRICH.

IN the representative institutions the engineering courses are now so organized that the junior student enters the engineering laboratory fresh from work in the physical laboratory. Advanced work along similar lines is carried on in many cases after the student has entered upon his professional studies. The earlier training is chiefly by way of illustration and demonstration, familiarizing the student with the phenomena, principles and laws of physics. The later training acquaints the student with some of the exact methods of modern experimental work. In consequence of such work, the engineering student should early assume toward all phenomena and problems in the realm of physics that attitude so characteristic of the scientific mind. Granting its thoroughness there is less necessity for attempting similar training in the engineering laboratory. More time is therefore available for developing the latter along engineering lines.

The work of physical and of engineering laboratories naturally overlap each other. No hard and fast line can be drawn between them. It becomes daily more impossible to define clearly their respective limits with each advance in physical science and growing industrial applications of the same. In the engineering laboratory are investigated the properties of water, steam, gas and electricity with special reference to their industrial applications; the chemical, physical, mechanical, electrical and magnetic properties of materials, as the case may require; the functional relations of mechanisms, machinery and prime movers, and their performance in detail or in the aggregate.

The bearing of these considerations upon electrical laboratory training is obvious. Preceding experimental work with new electrical appliances or processes there should be carefully arranged work along the following lines: study, inspection, illustration and demonstration, operation. By thorough study of actual and typical appliances the necessary preliminary electrical and mechanical data are secured. By inspection the student is assured of the electrical, magnetic and mechanical condition of the apparatus essential for successful operation of the same. By way of illustration and demonstration, he is familiarized with the phenomena and principles underlying the functional working of apparatus and the handling of instruments and circuits. By operation the student acquires that familiarity, facility, confidence and resourcefulness so essential for the satisfactory handling of electrical circuits and appliances.

Training in handling electrical machinery is quite as essential in electrical measurements. The one should be done and the other not left undone. If with all of his familiarity with galvanometer work, the young electrical engineer is left to the mercy of the wireman or the operating engineer, his laboratory training has been incomplete. A knowledge of the behavior of electrical machinery and confidence in handling electrical circuits is becoming more necessary with each widening use of electricity. The utilization of alternating currents, and the operation of alternating-current machinery, constitute today a most interesting and important field, one with which the electrical student cannot become too familiar. It is the result of experience that students who have been given a course of electrical laboratory training involving study, inspection, illustration and operation, have a better understanding of testing work than if they had been put at once into the latter without attention to the former.

*Abstract of a paper read before the Society for the Promotion of Engineering Education, New York meeting, July 2-4, 1900.

INEFFICIENCY OF ARTIFICIAL ILLUMINATION.*

BY DR. JOHN HENDERSON.

PERHAPS one of the oldest of all practical applications of physics has been that concerned with the production of artificial light, and it is strange that, although the problem has been worked at for so many years, it has even now, at the end of the enlightened nineteenth century, received a very unsatisfactory solution. When we compare, say, the great increase in efficiency of the steam engine and dynamo of the present day over that obtained twenty yearys ago with the increase in efficiency of our sources of artificial light, we are bound to admit that a very small advance has been made. This unsatisfactory state of affairs is due largely to the fact that the true nature of the phenomenon of light itself has been demonstrated by physical science only within very recent years, and a thorough knowledge of the nature of any phenomena to be reproduced must in all cases precede any satisfactory and efficient production of them.

Under the best conditions obtaining at present, out of every 100 tons of coal delivered at gas works or electric light stations, something like 98 tons are, as far as the production of light is concerned, absolutely wasted, and go to produce useless heat. When one considers the enormous quantity of coal used annually for the production of artificial illumination, the absolute waste of 98 per cent. of it seems little short of criminal.

Will the problem ever be solved? It must be confessed that at present the prospects are far from being bright. Some means must be found of exciting ether vibrations between the visible limits only, and of eliminating the slow, radiant heat waves. Whatever method may be eventually employed, it is interesting to note that already, on a small scale, the problem has been solved by the firely, the most delicate measurements having failed to detect any radiant heat in the light emitted by this little creature. Surely this ought to be an interesting subject for investigation by the physiological chemist, who, working in conjunction with the physicist, might enable us to get nearer the solution of this important question.

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